The California earthquake of April 18, 1906

California. State Earthquake Investigation ...

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THE CALIFORNIA EARTHQUAKE OF APRIL 18, 1906

REPORT

OF THE

STATE EARTHQUAKE INVESTIGATION COMMISSION

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IN TWO VOLUMES AND ATLAS

VOLUME I, PART II

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PART TWO.

ISOSEISMALS: DISTRIBUTION OF APPARENT INTENSITY—CONTINUED.

AREA OF THE SANTA CRUZ QUADRANGLE OF THE U. S. GEOLOGICAL SURVEY.

The distribution of intensity in the area of the Santa Cruz Quadrangle was studied by students of Stanford University, under direction of Prof. J. C. Branner. The contributors to data embodied in this part of the report are Messrs. R. V. Anderson, H. W. Bell, B. Bryan, R. E. Collom, R. Crandall, P. Edwards, H. P. Gage, F. Lane, R. Moran, R. L. Motz, A. F. Rogers, S. Taber, A. F. Taggart, F. W. Turner, and G. A. Waring.

Stanford University (J. C. Branner). — Referring to the group of dwellings southeast of the University quadrangle, there were 61 residences on the campus of Stanford University at the time of the earthquake. Out of 140 chimneys on these buildings, 104 were thrown down, or 74 per cent. The plaster was generally badly broken on the first floors of these buildings, and less injured tho generally more or less cracked in the second-floor rooms. At No. 13 Alvarado Row, first floor, several pictures 18 inches across, and hanging by cords 4 feet long, were swung so far that they were left with their faces to the wall. On the corner of Salvatierra and Aguello Streets, a frame building occupied by the Chi Psi Fraternity was so badly wrecked that it had to be abandoned. The injury done this building was due to its having stood upon posts 4 feet high and not well braced; the swaying of the building threw it off these supports.

President Jordan's residence, west of the quadrangle, had 3 brick chimneys, all of which were thrown down; the plaster was so badly injured that the first floor, the ceilings, and part of the second floor had to be replastered. This building rested upon a brick foundation about 4 feet high.

The Stanford residence, a mile north of the quadrangle, was so badly wrecked that it has since been torn down. The original building was of brick, and wooden additions had been built on the northwest and southeast sides of the brick portion. The additions stood upon wooden uprights 4 feet in length. The southeastern wooden addition was thrown from its supports and fell away from the older brick portion. The brick portion of the structure was badly shattered. In the grounds and parks about the residence there were many marble and bronze statues from 4.5 to 5 feet high, standing on pedestals from 2 to 4 feet high. These were all thrown down, except a few that were very securely bolted to heavy pedestals. There was no uniformity in the directions in which they fell.

Between the Stanford residence and the museum, a large 2-story brick winery had the 4 gable ends thrown down. The northwest gable fell into the building, the southeast gable fell outward, while the gables on the northeast and southwest sides fell outward.

Mr. Charles G. Lathrop's residence is not on the valley floor, like the other buildings in the immediate vicinity of the University, but stands on a hill of sandstone nearly 300 feet above the level of the bay. Out of the 4 brick chimneys on his house 2 were thrown down; 2 water-tanks 53 feet high (10-foot tanks on 43-foot supports) were not injured, but about two-thirds of the water was thrown from them.

Professor Durand's house, south of the quadrangle, is on a hill 160 feet above the bay and stands on the upturned edges of gravel beds that underlie the Santa Clara Valley. Of 3 chimneys, 2 were thrown down, and the plaster was cracked on the ground floor.

Of the University buildings proper, some were unhurt while others were completely wrecked. (See plate 102B.) They all stand upon the loose gravelly loam of the Santa

Clara Valley floor. As a rule, the older the buildings were the better they withstood the shock. Much damage was done by the throwing down of stone chimneys. The 150-foot stone chimney of the power plant was thrown down, crushing part of the boiler house and killing a fireman. The double-flued 60-foot chimney of the assay laboratory fell. The large stone chimneys of the dormitories were broken off at the roof edges and fell into the buildings. At Encina Hall, the men's dormitory, one chimney fell thru the roof and carried down a tier of rooms into the basement, killing one student. The south ends of the wings of Encina Hall were so badly cracked that they had to be entirely rebuilt. It was found that the injury done to the ends of the wings was due to the relation of these particular walls to the roof beams. Excepting the cracking of plaster, Encina Hall was not otherwise injured, tho it is a 4-story building, with basement and attic.

The chimneys also fell from Roble Hall, the women's dormitory, and did some damage to the roof and upper floors; but the building, which is of concrete, was otherwise unhurt.

The Chemistry building had 32 tile-lined stone ventilating chimneys projecting 12 to 16 feet above the roof, besides 2 ordinary stone chimneys; these were all thrown down.

The stone tower of the church was shaken to pieces, and in falling destroyed the parts of the roof immediately around the tower. The north gable end of the church was thrown outward into the quadrangle. (Plate 103B.)

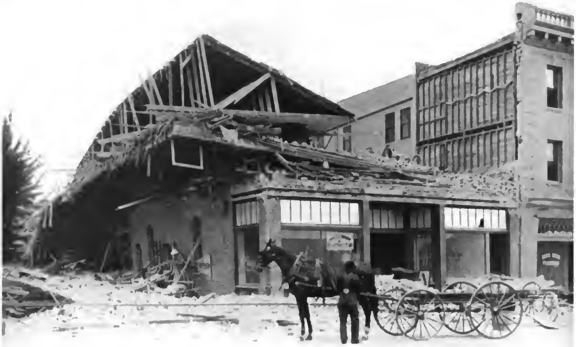
The top of the memorial arch was broken off down to the upper part of the frieze, and in falling it wrecked adjacent portions of the arcades to the east and west. (Plate 103A.) The parts of the arch left standing were cracked. The 2 smaller arches at the east and west ends of the inner quadrangle were slightly cracked near the top, but they were not seriously damaged.

Besides the damages to the church and the memorial arch, the most serious injury to the quadrangle group of buildings was done to the larger structures. The 1-story buildings, especially those that had been standing for several years, were not damaged beyond the occasional cracking of plaster; and even in these cases the injury was found to be directly related to the method of supporting the roofs upon the walls. The statues of the front façade were dislodged and one was thrown down. (Plate 100B.)

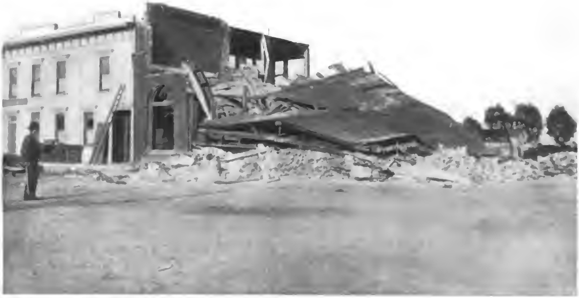
The 1-story buildings in the outer quadrangle had all been lately put up, and these were somewhat cracked, tho none of them was seriously hurt. The cracks were generally about the ends of the buildings and along the tops of the walls where the roof timbers rested upon them. The higher buildings of the outer quadrangle were more seriously damaged, especially those situated on the corners. These buildings are all three stories and basement. The towers on the inside corners of these buildings were all more or less broken and require rebuilding. The Civil Engineering building — three stories and basement — at the southeast corner of the outer quadrangle had its outer walls badly cracked, especially on the north face, and about the tower at its northwest corner. Inside the plaster was injured more or less all thru the building.

The Geology building, at the southwest corner of the outer quadrangle, was the last building of this group to be put up. It was a 3-story structure, and had barely been finished; but it was not yet occupied when the earthquake occurred. Sections of the walls were thrown down from every face of the building. These sections extended from the eaves down to the second floor. The tower at the northeast corner was badly cracked and part of it fell. The plaster was broken on all the vertical walls, both on the outside walls and on the partitions, showing that there was much internal wrenching of the building. The walls of this building will all have to come down and be rebuilt from the foundation. (Plate 102A.)

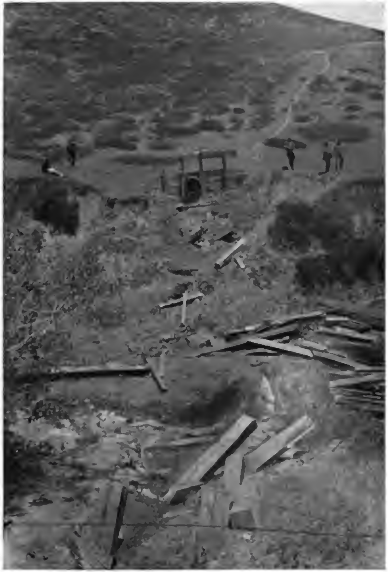
The inner arcades of the quadrangle were not much affected. At one place on the south side of the memorial court, where the arcades are not directly connected with any other building, they were so violently swayed that they seem to have come near falling. They were found to be 7.75 inches out of alinement after the earthquake, and the tops and bases of the supporting stone columns were chipped off. (Plate 105B.)



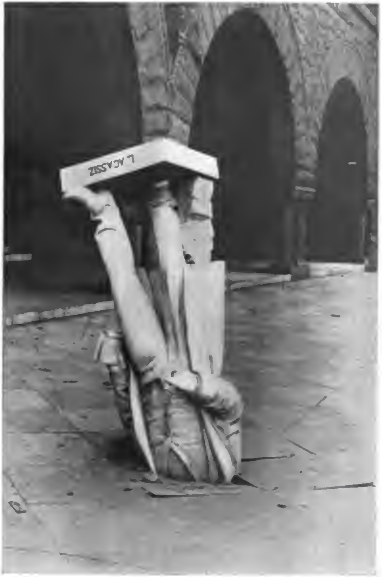
A. Wreck of 2-story brick building, San Mateo. Per J. C. B.



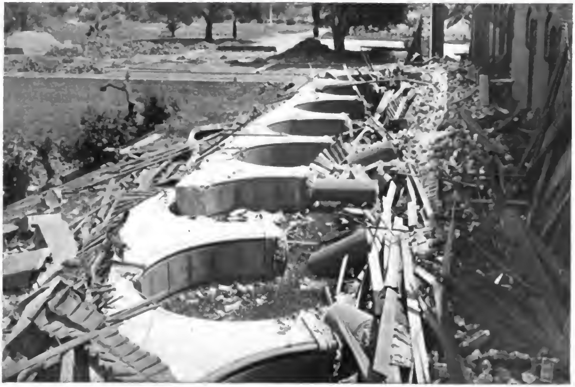
B. Wreck of 2-story brick building, San Mateo. Per J. C. B.



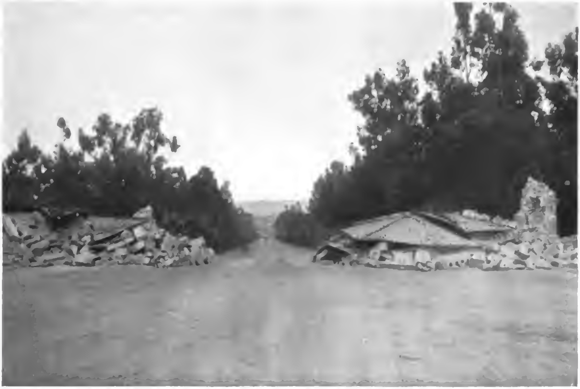
A. Trestle carrying a 30-inch water pipe across Frawley Gulch demolished by shock. R. L. H.



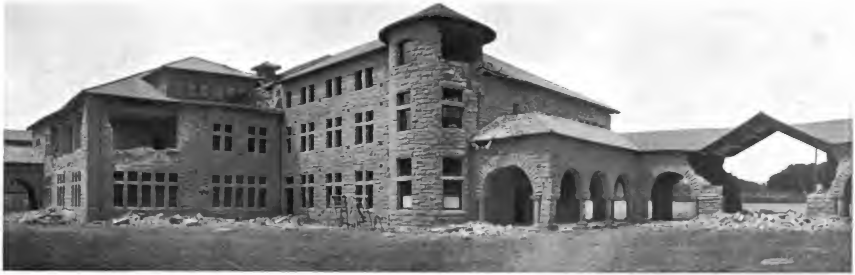
B. Statue of Agassiz thrown from its niche above arches, Stanford University. Per J. C. B.

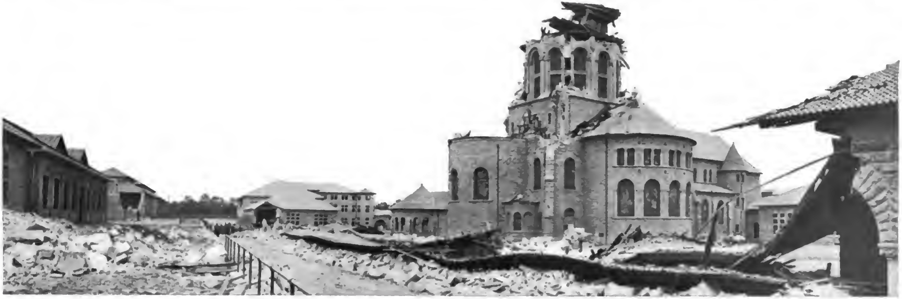


A. Destruction of arcade at Sacred Heart Convent, Menlo Park. R. C.



B. Gateway of Campus, Stanford University. Per J. C. B.





A. Geology Building, Stanford University. Per J. C. B.

B. Panorama of destruction, Stanford University. Memorial chapel in middle right. Per J. C. B.

The arcade along the south side of the outer quadrangle that was not directly connected with the other buildings was completely wrecked. The arcade in front of the French building on the east side and a corresponding piece in front of the Physics building on the west side of the outer quadrangle were thrown down. South of the business office, parts of the outer arcades fell. This is on the east side of the quadrangle. Parts also fell south of the Mineralogy building, on the west side of the outer quadrangle. (Plate 105A.) The arcades around the memorial court are only partly in direct connection with buildings. The free portions appear to have swayed so far out of the vertical that the bottoms of the stone columns supporting the arches were chipped off, or cracked at their bases. The 2-story woodworking shop of brick, south of the quadrangle, was badly damaged; and the forge building, next to it, also of brick and 1-story, was cracked.

The chemical laboratory, a new stone-faced building (two stories, attic and basement), was so badly cracked that most of the walls have to be rebuilt from the foundation.

The new gymnasium, a stone-faced brick building, was totally wrecked. (Plate 104B.) It had just been put up, and the inside work was not yet finished. The new library, also a stone-faced brick structure, was completely wrecked except a tower of steel on which its central dome still stands. (Plate 104A.) This building had just been put up, and was not yet finished on the inside when the earthquake occurred. The Museum building consisted of an older central portion built of concrete, and extensive additions of brick had just been completed. The new brick portions of the building were almost all thrown down, but the older concrete part was unhurt.

The ornamental stone gateway at the entrance to the university grounds, near Palo Alto, was thrown down. (Plate 101B.)

The water-tank at the Faculty Club-house was wrecked and a water-tank in the fields east of Alvarado Row was overthrown. The large covered tanks west of the stock farm, beside the county road, were not thrown down, but much water was spilt from them.

Palo Alto (A. F. Rogers). — The most interesting effects of the earthquake in Palo Alto were those which showed movement of buildings and those which gave evidence of twisting. A number of buildings moved toward the southeast 1 to 6 inches or more. Some buildings were left out of plumb and usually they were inclined to the southeast. In other cases, buildings collapsed and fell toward the southeast. It should be remarked that practically all houses moving to the southeast were those situated on the streets running northwest-southeast. Very few buildings on the avenues (running northeast-southwest) were moved at all. The moved buildings stand approximately at right angles to the fault-line southwest of Stanford University.

A change in the direction of the earthquake movement is suggested by the fact that in several cases the chimneys were apparently twisted from their normal positions. The same is true of several houses that collapsed. The twisting was clockwise in some cases and counter-clockwise in others. A remarkable case of twisting was shown in the house at 727 Cowper Street, where picture frames were tilted from the normal positions.

Chimneys were mostly knocked down, those that remained standing being for the most part in the centers of the houses. The direction of their fall was apparently accidental. A curious case is that of three 1-story frame houses, exactly alike, at 317, 323, and 329 High Street. The chimney on the house at 329 remained standing, while the chimneys on the other two houses fell.

The data upon which these conclusions are based follow:

737 Channing: Small one-story frame house without foundation; chimney standing.
845 Webster: One-story frame house with wood foundation; chimney standing. Chimneys were thrown from the two one-story frame houses next to it.
434 Middlefield: Two one-story shingle houses; chimneys standing.
427 Middlefield: One-story house; chimney in the center of the house stood. Next door, same kind of house, chimney at end of house fell.
667 Hamilton: One and one-half story frame house; chimney in center of house stood, while one at side of house fell.
557 Hamilton: Two-story frame house; chimney standing.

Hamilton and Middlefield: Two and one-half story frame house; chimneys standing. Chimneys down in houses around it, both one-story and two-story houses.

368 Lytton: Very small frame house without foundation; chimney standing.

Hawthorne near Waverly: Several small houses; chimneys in center of houses standing. Side chimneys on small houses across the street from these were down.

171 Cowper: Tiny one-story frame house; chimney on side of house standing.

317, 323, and 329 High Street: Three one-story frame houses exactly alike, and chimneys in same positions on houses. Chimney at 329 standing; the other two down.

310 High: One and one-half story house; chimney in center standing, one on side down.

Kingsley and Bryant: Two-story stucco house; chimney standing. No damage.

1329 Waverly: Low one-story shingle house; rather high chimney standing.

Boyce Avenue: Two-story rather low frame house; chimney standing.

Guinda Street: Two frame houses, one one-story, other two-story; chimneys standing. Chimneys fell from houses on both sides.

Hamilton and Fulton: One and one-half story frame house, chimney cracked but standing. Very small house next to it, chimney down.

465 Hawthorne: One and one-half story house (first story brick); apparently no damage except chimney down.

347 Melville: Two-story stucco house; chimneys all down.

Forest Court: One very low frame house; chimney down.

253–255 Homer: Two-story double stucco house; plaster slightly cracked, chimneys down.

Evidences of Twisting.

1110 Bryant: Small one-story frame house; chimney at center of house twisted slightly counter-clockwise.

121 Emerson: Small one-story frame house; chimney in center twisted clockwise.

Waverly near Lytton: The Palo Alto Academy, an old two-story frame house, completely collapsed, falling toward the southeast and apparently twisted counter-clockwise.

Emerson, near University Ave.: Two-story frame house was moved off its foundation toward the southeast, and twisted clockwise.

711 Cowper: Pictures on walls; some remained straight, others were twisted as shown in the sketch, showing the four walls of the room. The pictures on the northeast and southwest walls were observed in one room and those on the northwest wall in another room. (See fig. 55.)

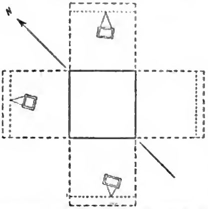


FIG. 55.—Diagram showing displacement of pictures on walls of rooms.

Movement of Buildings.

627 Waverly: Two-story frame house high above the ground and resting on brick foundation; lower part of house moved toward the southeast so that it had to be propt up.

711 Cowper: One and one-half story frame house high off the ground; 6 inches out of plumb in rear.

745 Cowper: One and one-half story frame house, high off the ground; several inches out of plumb.

538 Emerson: Two-story frame house; first story moved 2 inches toward southeast.

439 Alma: One-story stable moved a little to the southeast.

129 Emerson: Two-story frame house several feet above the ground was moved 3 feet toward the southeast and set down on the ground.

Luscher Building, 251 High: Two-story frame building; moved toward the southeast several inches, and apparently twisted counter-clockwise.

Palo Alto Hotel, Alma and Lytton: Three-story frame hotel moved toward the southeast.

Greenhouse, near San Francisquito Creek: Very little damage; a few panes of glass broken. The benches moved toward the southeast from 0.5 to 1 inch.

Ruthven and Cowper: New one and one-half story shingle house with concrete foundation; chimneys standing. House propt up on southeast side.

Dudfield Lumber Yard: Piles of lumber moved in various directions, but mostly toward the southeast.

Forest and High: Lumber shed; lumber piles on each side of open central space partially collapsed. Lumber piles on northwest side moved toward the southeast; those on southeast side remained in place.

Bleiber Blacksmith Shop: Two-story frame building; lower story moved 4 inches toward the southeast.

Alma, west of University: New three-story artificial stone building fell toward the southeast.

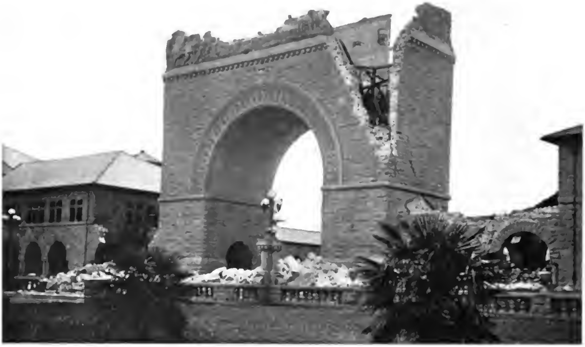
Alma, east of University Avenue: New two-story artificial stone building; collapsed and fell toward the southeast.

441 High: Two-story brick business house; first story moved toward the southeast.

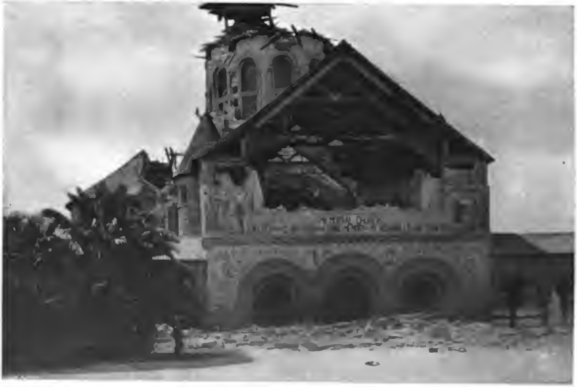
Miscellaneous.

The bridges across San Francisquito Creek, at Bryant Street and Middlefield Road, apparently were not damaged.

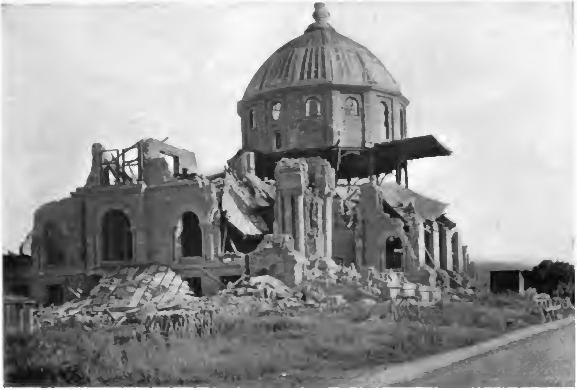
University Avenue and Romona Street: Jordan Building; three-story stucco business building. Plaster on first story badly cracked.



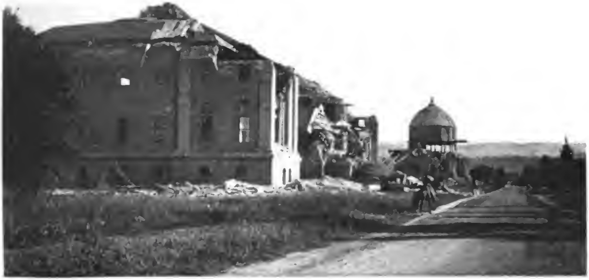
A. Ruin of Memorial Arch, Stanford University. Per J. C. B.



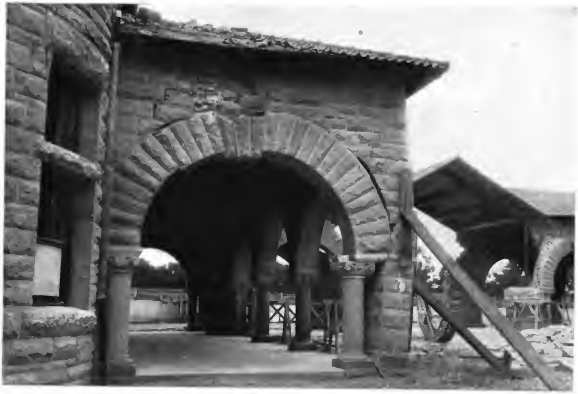
B. Front View of Memorial Church, Stanford University.



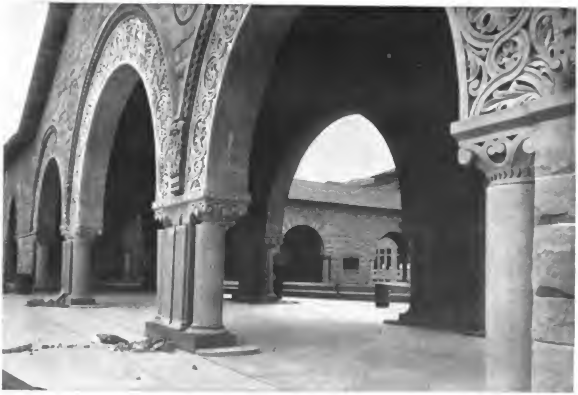
A. Wreck of Library Building, Stanford University. Per J. C. B.



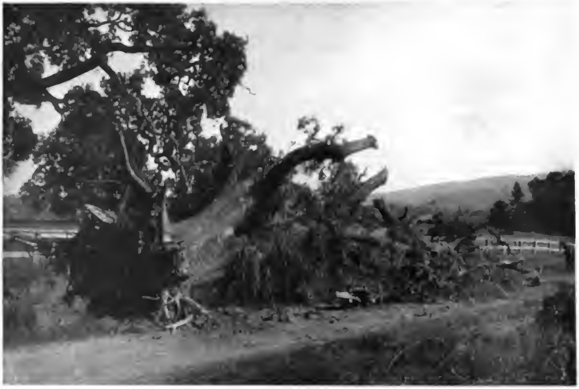
B. Wreck of Gymnasium Building, Stanford University. Per J. C. B.



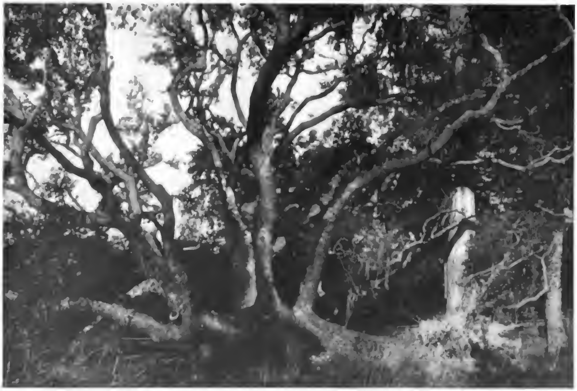
A. Wrecked arches, Geology Building, Stanford University. Per J. C. B.



B. Arches that moved on their supporting columns, Stanford University. Per J. C. B.



A. Tree overthrown by earthquake, west of Searsville Lake. Per J. C. B.



B. Live oak uprooted by earthquake, west of Searsville Lake. Per J. C. B.

Menlo Park (H. P. Gage). — At the Catholic Seminary near Menlo Park, a 4-story brick building, the upper part of many of the walls fell; towers and chimneys also came down; arches were sprung apart, allowing their keystones to drop, catch, and hang. There were many cracks in all the walls which remained standing; the capstones above the windows on the fourth floor fell out. The chapel behind the northeast side wall was thrown in a heap. The 1-story brick buildings back of the large one were little damaged; a wooden tank was uninjured, altho it was on an 80-foot tower like the one in the building which fell. The round power-house chimney (35 feet high) was cracked in the middle and the top broken off. A mile nearer Fairoaks Station, a water-tank only 12 feet high was thrown down. With this one exception all the tanks on this side of the county road appeared to be standing.

(F. Lane.) — A water-tank beside the road, passing north of the cemetery 1.5 miles southwest of Menlo Park Station, was thrown down; while one about 0.25 mile nearer the station on the same road was left standing. On the second road west of San Francisquito Creek, and running southwest from Menlo Park Station toward the Alameda de las Pulgas, three large trees growing together had been torn apart, and one about 2.5 feet in diameter had fallen. Water-tanks on the second road west of San Francisquito Creek were not thrown down. On the second parallel road west of the Creek, and leading southwest from Menlo Park and 1 mile from the station, the roof of a large 3-story brick house, which had been recently built, had collapsed, the bricks having been shaken from the walls down to the second floor. The Arcade of the Sacred Heart Convent was thrown down. (Plate 101A.)

Fairoaks. — On the road leading southwest from Fairoaks and about a mile southwest of that station, a newly completed 1-story bungalow had entirely collapsed.

(S. Taber.) — At a stable near Fairoaks (about a mile southeast of the junction of the Woodside Grade road with the road leading across University Heights) heavy carriages and wagons were moved sidewise 6 inches in a direction N. 37° E., but they did not roll out on their wheels. These carriages were placed on the northwest side of the barn.

(H. P. Gage.) — Following the road from Fairoaks toward Cooley's Landing, a house with poor underpinning fell over, also the woodshed near it. An engine mounted on a platform 2 feet from the ground was not upset. People reported new holes formed in the slough near Cooley's Landing, but their statements were not verified. No damage except broken chimneys was noticeable in the vicinity of the Landing, and solidly built houses seemed to be intact. One house on a poor foundation was knocked down; while the barns, tanks, etc., belonging to it were uninjured.

(F. Lane.) — South of Menlo Park and east of the Meyer Place on the west side of San Francisquito Creek, a crack about 1.5 inches wide ran for 20 feet along the edge of the county road parallel to and just above the creek, showing a half-inch vertical displacement, the lower side lying next to the creek. This crack appears to be due to the starting of the filled ground of which the road is partly made. The water in the reservoir of the Bear Gulch Company, 3.25 miles west of Stanford University, is reported to have been thrown about 25 feet beyond the dam on the southeast side of the lake. Water-pipes along the road leading from the reservoir toward Menlo Park had been pulled apart. The buildings in the neighborhood of the reservoir are of frame, and no great damage was done to them, except that the brick chimneys were thrown down.

Redwood (R. V. Anderson). — The intensity of the earthquake in Redwood City was about IX. Many buildings were partially wrecked and the new court-house was completely ruined. Over 40 houses in the town were moved upon their foundations, and a majority of the houses had the plaster badly cracked. Ninety-four per cent of the chimneys fell, and dishes and similar objects were universally thrown down. Along the two roads leading from Redwood to Portola, out of 23 big public water-tanks 20 were thrown down.

East of Palo Alto (S. Taber). — On the Embarcadero road, from the railroad crossing at Palo Alto toward the Bay of San Francisco, only about half the brick chimneys had been thrown down. Plaster on first-floor walls cracked, but it was not injured to any extent in the upper stories. Many houses showed little damage to plaster, even on the first floor. The tanks of the Palo Alto Water Company (at 1, map No. 22) had not been thrown over, but the frame (100 feet high) had slipt on the concrete foundation a maximum distance of about 0.5 inch in a direction N. 87° E. The water is reported to have slopt out of the reservoir on the east side. A water-tank about 0.5 mile nearer the bay (at 2, map No. 22) was standing, as was a brick chimney near it. Damage to houses in this section was directly due to high brick chimneys; plaster was sometimes scarcely cracked, even on the first floor of houses thus damaged.

Mayfield to Guth Landing (R. L. Motz). — In the town of Mayfield most of the houses are small, 1-story buildings resting on wooden foundations, and many of the chimneys were of terra cotta and wired to the roofs. Out of a total of 258 chimneys 183 fell — about 70 per cent. A few brick buildings were badly cracked, and the fire-walls were all thrown off. The plaster in the small buildings was somewhat cracked, while in the larger buildings the damage done to plaster was more marked. The concrete bridge over Madera Creek, on the county road 0.5 mile southeast of Mayfield, was not cracked. A half mile further southeast along the road, 2 water-tanks and 3 chimneys (2 brick and 1 cobble-stones and lately built) were standing. A short distance nearer Mountain View Landing there were fallen or damaged chimneys (at 4 and 5, map No. 22).

At Guth Landing a large brick warehouse facing N. 87° E. had its sides cracked, lost a few bricks at the top, and had the upper part of its east and west ends knocked out. From Guth Landing southward along the road into Mountain View, the effects were uniform; chimneys were down with two exceptions, there was little or no damage to plaster, and the flow from bored wells had increased. In one case a wind-mill (at 6, map No. 22), which had been in use for years to pump water from the well, was no longer found necessary, but the artesian water was muddy.

Mountain View (H. P. Gage). — On the county road between Mayfield and Mountain View, concrete bridges were uninjured, water-tanks were left standing, and the smaller or more solidly built chimneys uninjured.

(R. L. Motz.)—In the new town of Mountain View, built mostly in the vicinity of the railway station, 6 brick structures, including the Pacific Press and the cannery buildings, were seriously injured. Out of 271 chimneys, 206, or 76 per cent, fell; out of 46 large water-tanks 20, or 43 per cent, fell. In the Mountain View Cemetery there were 26 large monuments; of these 11 fell and 7 were shifted, while 13 slab headstones out of 27 were thrown down. In the village of Old Mountain View 75 per cent of the chimneys (31 out of 41) fell, and 33⅓ per cent of the water-tanks (3 out of 9) fell.

(H. P. Gage.)—On the road leading southwest toward San Antonio Creek from the town of Mountain View, the houses showed no uniform damage. At one place south of the county road and two miles west of the Mountain View Station, the water-tank swayed and threw out several barrels of water during the shock, yet the plaster in the house was unhurt and only a few dishes were broken. At the next house, the chimney fell.

At the Weeks poultry ranch 2 chimneys fell, dishes were broken and plaster was cracked; but the water-tank was uninjured.

Two and a half miles southwest of Mountain View Station, beside the road running up San Antonio Creek, a water-tank was so badly wrenched that it had to be braced to keep it from falling; another tank, on a side hill west of San Antonio Creek, had collapsed. The house near the latter, in course of construction, lost an outside chimney. Following the road up San Antonio Creek on its southeast side, another house between the road and the creek had one chimney cracked and another thrown down; plaster had fallen in the second story, and sewer and underground pipes were broken. Much damage was also done to the houses on the hill southwest of where this road crosses San Antonio Creek. In one of these 3-story houses, the plaster was partly off the first floor walls, and windows were broken. The second house was so shaken that it shifted several inches upon its foundations. A 1-story cottage close by was little damaged; and in the pumping shed, bottles, cans, etc., standing on a narrow shelf did not even fall down. The chimneys were thrown down on the ranch house at Hidden Villa, two miles northwest of Black Mountain Triangulation Station, but there was no great damage otherwise. Big blocks of rock are said to have been shaken loose from the mountain and to have rolled down the slopes. One of these rolled into the chicken-house, and others broke the water-pipes at several places farther up the gorge.

On the road running southwest from Mountain View Station toward San Antonio Creek and 1.75 miles southwest of the station, a water-tank 8 feet high was thrown down. In the village of Mountain View, 0.5 mile southwest of the railway station, one chimney on a small house, and projecting 5 feet above the roof, was left standing; while another chimney on the same house was thrown down. On the road leading north from Mountain View, and 0.25 mile from the station, one chimney fell; but another, 1 × 2 × 3 feet was standing. The latter was braced with iron bolts, however. The plaster in the house was cracked, though not very badly, and the foundations were unhurt.

At the Ynigo ranch, 3 miles northeast of Mountain View Station, the house is large and old. Here the chimneys fell, one going down through the roof. The plaster was only slightly cracked. Frail sheds and water-tanks 20 feet high on light supports were not thrown down, and plumbing in the house was apparently undisturbed. There was an artesian well at this place which had, before the shock, flowed only slightly or not at all, and a wind-mill was used to raise the water. After the shock, it was found that the casing had been shoved up 2 feet, damaging the pump. The flow of water was increased and black sand was brought up. Another well at this ranch was unaffected.

At Jagel Landing there was but little damage. One chimney was unhurt, and another was slightly twisted.

The concrete bridges over Permanente and San Francisquito Creeks showed no new cracks. In the low lands northeast of Mountain View, all the chimneys except one at the Mascot Gun Club preserve had been thrown down, and water-tanks had fallen except where they had been especially well braced. The same was true in the vicinity of Sunnyvale. Between Sunnyvale and Lawrence a brick winery was destroyed, and a tank and wind-mill were thrown to the ground. On the second east-and-west road directly south of Sunnyvale, for a short distance toward Stevens Creek, a few chimneys were left standing; but the damage was generally uniform as reported above.

(F. Lane.)—A 3-story brick wine distillery in the northeast corner of the San Antonio grant, 3.5 miles south of Mountain View Station, was totally destroyed by the shock. This building was on the side of a hill. A 3-story frame house near it lost its chimney and was tipt to one side. A half-mile south of the winery, a water-tank beside the road had been destroyed. At the southeast corner of the same grant, a 2-story frame house (Sellinger's) was thrown from its 4-foot brick foundation and badly damaged. The road in front of the house was cracked, but probably on account of the steep slope below the road. South of the house, across Stevens Creek, there was a landslide 100 feet in width on the steep face of a bluff.

(S. Taber.)—The concrete bridge over Stevens Creek on the county road below Mountain View was not cracked, but at the brick yard, at the junction of the San Jose road with the road to Jagel Landing, a high chimney and a pile of brick had fallen over.

Saratoga to Congress Springs (F. Lane). — At Saratoga some chimneys were knocked off, but among those standing was a high chimney built on the side of a 1-story house. A wind-mill with a large tank had not been injured and no other damage was apparent.

On the Azule Springs road, all the 1-story buildings appeared to be in good condition, and few effects of the shock were noticeable. Near the place where five roads fork, one mile north of Azule Springs on the road running southeast from the forks, there was a 6-foot drop on the road caused by a section sinking in a solid piece on a long slope, without much disturbance in its vicinity. At the cross-roads halfway between Saratoga and West Side, the Lincoln school-house, on wooden supports, was thrown from its foundation and badly damaged. The tank behind the school-house was standing, as were all the tanks on the road from Saratoga to West Side except the one nearest the latter village. Only one more effect of the shock was noted in this vicinity; namely, the bridge over Stevens Creek, on the road running due east and west from West Side, was rendered unsafe for horses by being shoved a foot out of place.

On the Stevens Creek road, just after leaving the Saratoga road, one house near the junction of the two roads was shaken and dishes were broken, but the brick chimney was intact. Near the house a crack 2 inches wide showed a downthrow of 2 inches on the west side. A vacant house at the next turn, 0.5 mile southeast of Stevens Creek, had lost its chimney and leaned with the slope of the hill. Near this house a large area of ground, extending for 150 feet, had been torn up in a direction of N. 3° W., and a slide formed which almost blocked the road.

At the Borger place on the Stevens Creek road, the chimney was shaken down; the house, which stands on a high but well-built stone foundation, was not damaged otherwise. Wine was spilt in the cellar by the force of the shock. Further northwest along this road other disturbances were noted with increasing frequency; small cracks crost the road due north and south.

On the northeast side of the creek, 0.25 mile south of the place where a road turns northeast from the Stevens Creek road to go up Monte Bello ridge, there was a large landslide about 0.5 mile long and terraced from the top of the mountain.

The short road which runs northwest along Stevens Creek for a couple of miles beyond the junction with the cross-road which connects with the Monte Bello ridge showed an exposure of serpentine with cracks running along it N. 3° W. The cracks at the widest point measured about one foot. In the serpentine area the ground was badly broken up, and in one place it was covered with 3 feet of water. (Observation made April 22-23.) Following the road northwest beyond the terminus shown in the map, many cracks were seen, due to big landslides. Fallen trees have rendered the road impassable; boulders and dead trees still fell occasionally; even while the observer was there a large tree fell not 10 feet from him, loosening rocks and soil.

Just south of the two houses near the southern end of the cross-road leading toward the Monte Bello road from the Stevens Creek road, a break ran due east and west; it was 2 inches wide with a downthrow of 0.25 inch on the west side. Only dishes were broken in the house, a 1-story frame structure without chimneys, tho it stands above the big slide which was just mentioned. Another crack 4 inches wide was found in the road above the house.

The village of Congress Springs had not been shaken very badly. All water-pipes and tanks were intact and very little timber seemed to have fallen. The car tracks on the curve near the path to the spring had been thrown over toward the bank for about 20 feet of the curve, a 4-inch displacement resulting. The 2-story stone building of the Saratoga Wine Company was partially thrown down, and the side nearest the road had to be propt up to keep it from falling. At this point several cracks were noticed in the loose alluvial material of the road, almost at right angles to each other.

Stanford University to Portola and Woodside (S. Taber). — Going southwest from Stanford University along the road leading up San Francisquito Creek (at 8, map No. 22), on the banks of the creek many dead limbs were broken from trees, and a dead oak

2 feet in diameter was broken off about 20 feet from the ground. But little damage was done at a house a short distance farther west. On the north side of the creek (at 9, map No. 22), the 12-inch cast-iron pipe of the Stanford University water-main, buried about 3 feet deep, was cracked, allowing the water to spurt 20 feet into the air.

Beside the road just west of Searsville reservoir, a living white oak 6 feet in diameter was uprooted by the jerk of the earthquake shock. (Plate 106A.) At the Searsville dam the waste way is 45 feet wide. The water running over the spillway was 4 inches deep before the earthquake, but afterward it increased to 5 inches; more water was also noticed in the creek that empties into the lake.

The Preston residence, about 0.5 mile south of Searsville Lake, lost its chimneys. Along the road leading from Searsville Lake southeast thru Portola, the water-tanks were all thrown down, except one near the junction of the Portola road with the Alpine road.

The bridge at the north end of the village of Portola had the ends thrust together so that the planks forming its floor were thrown out of place. In Portola, brick chimneys were all down and water-pipes were broken. The Portola store was thrown off its foundation. The Catholic Church in the village is a frame building that stood upon an underpinning of posts about 3 feet high. This building was thrown bodily about 2 feet toward the north, apparently thrust over by the underpinning when it gave way. The Portola school-house was also thrown from its foundation, which was about 3 feet above the ground. Two small dwelling-houses southeast of the school-house and on the south side of the road were thrown from their foundations.

Following the Portola road from Portola toward Woodside, the houses showed considerable damage, with chimneys down. The water-tank at the fork of the road in front of Mr. Preston's house was thrown down, and the big tank at the fork of the road, at the site of the old village of Searsville, was also thrown down. The white oaks in the field north of the road had also many large branches broken off by the shock. A shanty between the 2 bridges (at 11, map No. 22) was down flat; and in a few cases the underpinning of houses had given way, the houses having settled in consequence. Small trees were overturned and fences broken. A large live oak had its top broken off about 20 feet from the ground (at 12, map No. 22); at the place of fracture the tree is about 3 feet in diameter.

Taking the western road past Newman's, which is at the place where this road crosses Bear Creek, from Searsville Lake to Woodside, two especially well-built water-tanks beside the road, tho well shaken on their foundations, did not fall. On the south side of the road, about 0.25 mile southeast of Mr. Folger's, a large live oak was torn up by the roots (plate 106B), while several eucalyptus trees had branches jerked off. A strongly built 1-story house just below (13, map No. 22), and within 400 feet of the fault-line, lost all of its chimneys, but the plaster was only slightly cracked. Beds and other furniture in the house were jerked in directions parallel to the fault-line. A small bed standing in the northwest corner of a room was not moved, but a larger bed near the center of the same room was moved several feet. A water-tank a short distance northwest of the house, new and strongly built, about 15 feet above the ground, had nearly all of the water spilt out of it. An eye-witness says that the water was thrown high up on the northwest and southeast sides. The water-pipe running from the house to the pump was bent in a curve toward the northwest, and where it entered the pump-house, the boards were broken on the southeast side of the pipe. The other pipe (also 4 inches in diameter) had the threads stript off at a joint, and the ends of the pipe pulled apart for a distance of 2.5 to 3 inches. The pipe was new and buried a few inches below the surface of the ground. A large oak tree standing 200 feet or so from the house had large limbs broken off by the shock. At the Folger place, between Newman's and Portola, the chimneys were all thrown down.

On the west side of Bear Creek and north of the road along the foot of the mountain near Woodside, a 1-story sandstone house had its south wall thrown down, and was otherwise badly damaged. About 50 feet of stone wall, laid with mortar, along the side of the road, 3 feet high and 1.5 feet wide, was thrown down. A tank at the cross-roads in Woodside was left standing. The upper part of a brick winery 1½ stories high (at 26, map No. 22) was demolished, the roof being split down the middle and smashed to pieces. A house 1½ stories high (at 14, map No. 22) was thrown toward the southeast, the underpinning giving way in front. The house was badly damaged. Water in a large tank near the house spilt out on the southeast and northwest sides.

At the very end of the short, crooked road mapped as running northwest from the village of Woodside, there was a well-built 1-story frame house, of which the brick chimney had been thrown down; the plaster of the house was only slightly cracked. Near this a large water-tank was thrown over; another remained standing but had the shingles knocked off the roof on the northwest side by the force of the water dashing up against it. The old adobe house at the cross-roads in the village of Woodside was thrown down, the posts and supports left standing leaned at a considerable angle toward the northwest.

A large frame house (Mr. Josselyn's residence), north of the road and close to West Union Creek, was demolished; while another on the opposite side of the road, and just south of the bridge, was not badly damaged. The concrete bridge over West Union Creek, 1 mile south of the point (14, map No. 22), showed a few small cracks. From this point on up King's Mountain road, as far as the summit, there were no cracks nor landslides.

Page Mill and Alpine roads (S. Taber). — All brick chimneys along the upper part of this road were thrown down. At the Clarita Winery crockery was broken and milk spilt from pans. On the road from Clarita Vineyard to the Allen place (at 18, map. No. 22), several small cracks 0.25 to 0.5 inch across ran east and west; numerous cracks intersected (near 18, map No. 22) in various directions, while some large ones running parallel to the contour lines were probably due to earth slipping. Judge Allen's in the valley, and several smaller houses, were thrown from their foundations and otherwise badly damaged.

Following the Alpine road up Corde Madera Creek, cracks were common on the outside or filled portion of the road, and these were generally parallel with the embankment. The steep southern slope of the ridge just north of the Alpine road, along its lower course, was favorable to landslips. At many places huge masses of rock had been thrown down from these steep bluffs into the road, completely blocking it up. On the south side of the creek the slopes were not favorable to landslips, but there were several of them; and at one point, about a mile from the summit of the ridge where this road enters the Page Mill road, one slide carried away the entire roadbed for a distance of about 300 feet.

(H. P. Gage.)—Following the Page Mill road westward from Black Mountain toward Langley Hill, a 1,000 gallon tank was undisturbed, but 3 live-oaks near by were uprooted, one of them being a large tree with a 12-foot base. These trees were in a rather dry soil, yet none of a grove of trees growing in moist soil was overturned. Farther west up the road which loops toward Langley Hill, a big crack running east and west, caused by a slide, showed a drop of 8 inches on the north side; and from here on down to the Alpine road the road was badly cut up with slides, but was not impassable. On the steep grade of Langley Hill a slide had moved 30 feet. At the ranch houses there was little damage done by the shaking save sometimes a fallen chimney or a few broken dishes. At one ranch the people reported that cows were much frightened during the shock.

(F. Lane.)—Along the ridge road southwest of Stevens Creek, separating Santa Clara and Santa Cruz Counties, there were some cracks due to landslides. Sandstone blocks, some of them 6 feet in diameter, had rolled down the hills toward the creek. People at the houses along this road stated that the shaking had been severe, with loss of a few chimneys but very little destruction otherwise. No evidence of cracks could be found upon the side road. At a house situated at the junction of four roads about 3 miles west of Congress Springs, no damage was reported, tho the inhabitants were up at the beginning of the shake and say that it was accompanied by considerable rumbling and that the shocks which followed were preceded by a sound like a blast.[1]

King's Mountain down Purisima Creek (S. Taber). — At King's Mountain House, brick chimneys were knocked down and some dishes were broken, but no damage was done to the house. Cream was spilt from the milk pans on the southwest side. On the Cahill Ridge road leading northwest from King's along the crest of the ridge, little damage was noticeable. An old woodshed was thrown down (at 21, map No. 22), and about a mile farther on the top was broken from a large redwood tree about 75 or 100 feet from the ground (at 22, map No. 22).

Following the trail from King's Mountain House down Purisima Creek, a large slide on the northeast side of the creek had filled the road to a width of about 100 feet (at 23, map No. 22). The buildings at Hatch's Mill, just below (24, map No. 22) were not damaged, but a little farther down several cracks were found, one 8 inches wide and running S. 23° E. On the northeast side of the creek, just below Borden's Mill, a big slide had dammed the creek to a depth of 25 or 30 feet (at 25, map No. 22). The slide was between 0.25 and 0.5 mile long. The buildings at the mill showed no damage, but a bridge just above the mill was crusht by a slide from the south side of the creek.

Bear Creek (H. P. Gage). — Between Redwood City and Woodside, all of the public water-tanks were thrown down or had to be rebuilt. On the Bear Creek road, southwest of Woodside, there were many cracks caused by landslips down steep banks. The tops of 2 partly decayed trees, one a redwood and the other a spruce, had been broken off where the diameter was 2 feet. Near where the first trail branches to the right from this road, an old oven built of clay and stone, 4 feet high, was cracked, and an old barn was badly damaged. At the point where the road itself becomes a trail there is a log cabin, probably used as a summer camp. This cabin was locked and had apparently remained undisturbed since the earthquake. The floor is about 6 feet above the level of the ground. Table, benches, chairs, and all the bottles and utensils, except a coffee pot, were overturned. The table was solidly built and measured 4 by 8 feet. About a mile east of this cabin, at the end of another trail, was a 1-story frame house; a bed on the first floor was moved by the shock 8 feet to the middle of the room, tables and chairs were displaced, and dishes were broken. A house and dairy between this place and the road were moved on their foundations, and water was spilt out of pails from northeast to southwest. Tops of spruce trees were broken by the shock. Four miles farther southwest, along the trail toward the San Gregorio road, people reported that all the stoves on the first floor of their houses were overturned during the earthquake, with the exception of a kitchen range which was twisted around 6 inches. Their dishes were also broken. Just south of the junction of this trail with the San Gregorio road, a 2-story house had been shifted on its underpinning and some plaster was broken. A water-tank 20 feet high fell at this point.

Half Moon Bay, Purisima and San Gregorio (S. Taber). — Following the road along Pilarcitos Creek toward Half Moon Bay, many cracks and slides were found on the ocean side of the ridge, but few on the east side. All of these seemed due to slipping of the earth. At one place there had been such a large slide that big blocks of sandstone had fallen down into the road. Here and there along the road big cracks had opened, parallel with the road and the creek where the slope is very steep, and promising to make the road impassable by landslides, should a heavy rain come.

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[1] Mr. Lane adds: "While I was there, however, we had a slight shock and I noticed neither blast nor noise."

Just north of the bridge over Pilarcitos Creek, north of the town of Half Moon Bay, an adobe house west of the road was thrown down by the earthquake, killing 3 people (at 30, map No. 22). The concrete bridge was badly cracked, as were the approaches at both ends. Just south of the bridge, several small cracks in the low ground west of the road permitted water to spout up, bringing sand with it. In the town of Half Moon Bay many buildings were badly damaged, some old frame houses and the brick bank building being flat, while the upper half of a 2-story brick structure was demolished. The Mosconi Hotel, a 2-story frame building, had plaster shaken from the side walls of the first floor only, while the ceilings of these rooms were not cracked.

In Half Moon Bay it was reported that there was no evidence of any change of level along the coast. The streams on the west side of the mountains were said to have doubled in volume. The road along the coast from Half Moon Bay to San Gregorio showed comparatively few traces of the earthquake. The concrete bridge over Cañada Verde (at 31, map No. 22) was slightly cracked, and 0.5 mile farther south a water-tank lay flat across the road.

At Purisima the chimneys were all down, and crockery was broken. The intensity of the shock was apparently less at Purisima than at Half Moon Bay. According to various reports, a crack east of the road below Purisima, due to a landslip, extended for about 1,000 feet nearly north and south; and an earthslide on the side of a hill a mile or more farther south was about 100 yards long and 80 feet across.

At San Gregorio very little damage was done. The hotel lost only a little plaster and a few dishes. Turning eastward on the road along San Gregorio Creek, traces were found of increasing intensity. A mile from the town of San Gregorio, a water-tank 20 feet high was still standing, while a couple of miles farther east the creek was dammed up to a depth of 6 feet by a slide from its southeast bank (at 32, map No. 22), and all chimneys were down. Miss L. E. Bell reports that near Bellville a small alkali flat was raised about 3 feet. There was a landslide into the road for a distance of 300 feet, the height of the slide being 100 feet (34, map No. 22). Chimneys and tanks all thru the valley were thrown down.

(G. A. Waring.)—Of the 2 stores at San Gregorio, the one in the bottom-land suffered most, nearly all the shelf goods being thrown down. Cracks from 12 to 18 inches wide appeared in the cultivated bottom-land, and a water-tank was shifted on its platform 8 inches northward. In the Lobitos saloon a slot machine was hurled to the floor, and nearly all the bottles on a shelf running east and west were thrown off. Small cracks appeared in the ground at Lobitos, and a small slide occurred in the road 0.25 mile up the stream.

La Honda (H. P. Gage).—The inhabitants say that after the shock the creek rose about 4 inches and became muddy. At the hotel, plaster fell from first floor walls; the rest were little damaged. The plaster had already been cracked, however, by raising the house. Lamps were all shaken off the tables, and all the chimneys were down. Water spilt from the horse-trough in a northeast-southwest direction.

Near the Weeks ranch house, between La Honda and the summit of the ridge on the road leading to Redwood, an inconspicuous crack was noticed running east. It was about 2 inches wide, with no vertical movement evident. The north side of the crack, however, had moved fully 3 feet eastward. The crack simply marks a big slide which has been slipping for years, and which descended 3 feet during the earthquake. The Weeks house, a strongly-built frame structure, 2½ stories high, was badly damaged. A large outside chimney fell thru the roof to the first floor, and the plaster was fairly stript from the lower rooms and somewhat cracked upstairs. The sliding doors downstairs were shaken off their tracks, several windows were broken, the front door was cracked, and many of the door jambs were broken. The heavily built barn near the house was badly strained. The water in the reservoir was spilt from northeast to southwest. In an old house near the summit the stove was not moved at all, but the chimney built 40 years ago fell.

(S. Taber.)—For some distance on the west side of the summit sandstone blocks had been cracked off and scattered across the road. From the summit of the ridge to the Portola Valley, the only effects noted were the wreck of a ramshackle old barn and a 3-inch crack across the road (at 36, map No. 22), probably due to settling.

Congress Springs to Boulder Creek (B. Bryan). — From Congress Springs, following the road that passes along the valley, about a mile east of the Castle Rock Ridge, in a southeasterly direction toward the reservoir of the San Jose Water Company, evidences were found that the earthquake had an intensity of over IX. The walls of a stone barn had been thrown down, 1,000-gallon wine-tanks in a cellar had been shifted, and people in the houses were thrown down while trying to get outdoors at the time of the shock. In a house close by, at the south end of the dam, the first floor plaster fell. Poorly built foundations fell. Southeast of the reservoir the chimneys and water-tanks were down. Two water-tanks at and near the bend of the road (at 37, map No. 22), were standing, but 0.5 mile northwest of this place a water-tank had fallen. The water in the reservoir (at 38, map No. 22) had overflowed the 3-foot banks, but the water-tanks were standing. A short distance down the road, to the northeast of the reservoir, another tank was standing. A house 0.75 mile east of this reservoir was badly shaken, with loss of plaster and chimney. In the section a mile east of the fault-line (at 39, map No. 22) the shock was weaker. All the chimneys on cottages were standing as far as could be seen, as well as all the water-tanks. The bridges 0.5 mile southeast of the reservoir were considerably shaken. Cracks seemingly continuous in the direction of the fault-line ran thru the area 0.75 mile east of the fault-line. Two-story frame houses along the fault line 1 mile southeast of the reservoir mentioned were so damaged within that people were living outdoors; yet the shake had not broken a 6-inch flag pole on a 2-story frame house. A large redwood tree had been shaken down (near 40, map No. 22); the house near it had its chimney fractured down to the fireplace, and the stove and piano were thrown across the room. The water-pipes here were badly displaced and broken. The intensity was greatly diminished, however, near 41, map No. 22; chimneys did not fall, tho fractured; clocks were stopt; little rock was thrown down from a vertical outside wall 15 feet high.

On Deer Creek a large landslide started from near Grizzly Rock and slid westward, but changed its direction 60° or more farther down toward the creek. The mill in the creek bottom below the slide was partly buried, and one man was killed. It is 500 feet from the mill in the gulch to the top, at the point where the slide started. The slide covered about 25 acres of ground, and destroyed a lot of virgin timber from 3 to 10 feet in diameter. The slide material, which is 300 feet deep, is composed of soil, clay, and shale.

The shock could not have been very strong at 42, map No. 22. The houses stand on posts 10 to 15 feet high, but were not moved noticeably. Furniture facing most nearly north and south was thrown down, but not when facing in other directions. The inhabitants were badly frightened and ran outdoors without waiting to dress. On Bear Creek (at 43, map No. 22) a smaller slide had moved a few hundred feet, buried a hut, and killed one man. According to reports of men in this region, only a minute elapsed after the beginning of the earthquake before the slide was over. Down in the valley no cracks or other evidence of violent disturbance could be seen.

Farther southwest down Bear Creek, about 1.5 miles from the village of Boulder Creek, were evidences of a less severe shock. A chimney on a 1-story house did not fall, tho the furniture in the house was thrown down. Trees were violently shaken. A mile northeast of Boulder Creek a chimney on a 2-story house was down, but no buildings were moved or broken.

In the town of Boulder Creek, all chimneys were down except those on some 1-story cottages; these were cracked, however. People generally ran out-of-doors, but were not as a rule very badly frightened; some even stayed inside until they had drest. Water-pipes were not broken, but some plaster had fallen, and plaster was cracked everywhere.

Mr. Bloom, owner of a sawmill at the edge of the Big Basin, reports that the shock was less severe in the Big Basin region than at Boulder Creek; that there were no landslides on the road between the two places; and that, tho he had been nearly to the summit on the day of the earthquake, he had seen only one crack where the earth had started to slide.

(R. Collom.)—At Boulder Creek, on the east side of the stream, a small hill of about 150 feet elevation rises rather abruptly. Its sides are thickly covered with small trees and brush. Near the top, a large portion of the surface soil had been shaken loose, and had slid to the level of the creek, carrying trees with it.

At Ben Lomond no fissures nor other such evidences of the earthquake were to be seen. Inquiry showed this condition to continue in the country about the town. Broken chimneys were the only evidence. The inhabitants of Ben Lomond report several slight shocks during the night of April 21-22, 1906.

(B. Bryan.)—Going north from the village of Boulder Creek along the San Lorenzo River, only small wooden houses were seen, all with chimneys standing. There were few evidences of the force of the shock, except fallen redwood trees. Three dead redwoods had been snapt off from 30 to 50 feet above the ground; and farther on two more were noticed, one having broken and the other having been uprooted. A man who was at the sawmill, 8 miles north of Boulder Creek, at the time of the earthquake, stated that a few trees were torn up by the roots. Cordwood had been thrown down in several instances along here. A small landslide had moved across the road (at 44, map No. 22), which 20 men spent one and a half days clearing away. In the gulch the tops of a number of redwood trees had been broken off from 50 to 100 feet from the ground, the diameters at the point of fracture measuring from 10 to 14 inches. Up the road to the summit of Castle Rock Ridge no slides nor cracks were observed.

On Boulder Creek, coming southeast down the China Grade, the shock was strong, but apparently not so severe as along the San Lorenzo River. The people were badly frightened by the shaking, however. One man reported that no redwood trees fell and that only a few dead limbs were broken off. Near the junction of the first road leading from Boulder Creek into the Big Basin, an old landslide which covered about 2 or 3 acres, dating back to the previous winter, had been widened by the shock and its direction had changed. Only a couple of hundred yards farther down the road, some stacks of smooth split redwood logs (cordwood size) had not been shaken down.

A small earthslide had started (at 45, map No. 22), and a crack, perhaps due to the same slide, was noticed. For the next mile or so southeast, there was a considerable amount of cordwood along the road, none of which was disarranged by the shock; and no trees nor dead limbs had fallen. In the houses between this place (45, map No. 22) and the sawmill (at 46, map No. 22), the evidences of damage were more serious. At this first place visited no damage was done; people were awakened but did not get up; no trees nor limbs had fallen. At the next place, 1 mile southeast, people ran from the house during the shake and attempted to remove a sick man. Small objects were thrown down and a pendulum clock was stopt. At the house just southeast of the mill, the inside furniture was overturned, the stove moved, and the terra-cotta chimney split and fell; while branches were broken from redwood trees near the house. At the mill the same effects were noted, and others as well; tops of live trees, from 6 to 8 inches in diameter at the fracture, were broken off. From the point (46, map No. 22) down to the road leading to Bloom's Mill, 1 mile south of the point (45, map No. 22), the intensity seemed to have been less. A water-tank beside the road was quite unhurt; houses were not badly shaken; and only small objects — cooking utensils, etc. — were thrown down. At an old mill 2 miles southwest, however, a clock had been thrown upon the floor and broken at 5^h 11^m A.M. Half of the piled lumber had been disarranged, and the water-tank, built on a frame 15 feet high, was shaken so that it fell the next Monday night.

Ben Lomond Mountain to the Coast (B. Bryan). — At the junction of the Ben Lomond Mountain road (47, map No. 22), the house was empty, but there was no noticeable disturbance in the sheds or neighboring trees, tho a few hundred yards south a few dead limbs had been recently broken from the redwoods and one or two dead trees had fallen. Some other trees were so loosened at their roots that they have fallen since the earthquake. At the Ben Lomond Wine Company, a place 2 miles southeast of the junction of the roads (at 47, map No. 22), a well-built cottage had 2 tall chimneys still standing. People did not leave the house during the earthquake. Leaving the Boulder Creek road, and crossing Ben Lomond Mountain by the Eagle Rock road, the damage appears to consist largely of fallen chimneys. Small objects, such as fruit jars, china, etc., were thrown down, but only from shelves against north and south walls. People left their houses, but were not much alarmed.

No evidences of a violent shaking were to be found on the trail following southwest down Big Creek, either in trees or buildings, except where a small, half-decayed shack had been thrown out of plumb and a set of shelves overturned in another cabin. A table near these shelves was unmoved, and the bottles on top of it were standing. At the dam on Big Creek (at 48, map No. 22), no harm had been done, nor was any damage visible in 3 old shacks just below the dam. A half mile from this point cracks caused by slides were noticed on a very steep bank. Slight damage was done to the flume (at 49, map No. 22), which 3 men repaired in half a day. A few objects were thrown down in dwellings hereabouts. Near the junction of Scott and Big Creeks, a light terra-cotta chimney did not fall, but milk was spilt from pans at this place.

(H. W. Bell.) — At a house 1 mile southeast of the junction of the east and west forks of Waddell's Creek, a brick chimney was thrown down. Near a deserted mill at the north-end of Ben Lomond Mountain, a small landslide had carried trees and brush down to the creek, and tall trees had fallen along the road. At a new mill a short distance from the old one, about a mile northwest of Eagle Rock, it was reported that the shock was distinctly felt, but no damage was done. Dishes even stayed on the shelves. A steep bank beside the road showed small cracks, which could apparently have been easily made in the loose soil.

(G. A. Waring.) — At Swanton it was reported that a distinct noise, as of a team crossing a bridge to the northwest, had been heard preceding each shock. Dishes on a shelf running northeast and southwest were thrown off, while those on a shelf standing at right angles to these were unhurt.

(B. Bryan.) — At the school-house (50, map No. 22) the globes were overturned by the shock. The teacher said that she had heard from the people at the end of the trail just above, leading northwest toward Swanton, that the shaking had overturned only a few glasses, and that their pendulum clock did not even stop. At the next place, 0.5 mile southeast of the school-house, no damage was done, and the inhabitants were not disturbed enough to run outdoors. In the little settlement at El Jarro Point, the shock was so light that a small chimney with a terra-cotta top, making a height of 7 feet above the roof, did not fall; nor were similar terra-cotta chimneys on 2-story buildings thrown down, tho projecting from 3 to 4 feet. Glasses and bottles remained on the shelves in a bar-room.

At the lime-kilns (51, map No. 22) the shock had apparently been more severe, for tho no cracks were found in the kilns themselves, people ran from houses, small objects were thrown to the floor, and piles of cordwood were overturned.

(G. A. Waring.)—At the San Vicente lime-quarry, the intensity was found to have been considerably higher in the bottom of the canyon. A cow in the yard could not keep her feet, men could not walk to the door of the cook-house, and milk and water were nearly all thrown from the pans and kettles. Little or no damage was done to the buildings or furnaces, and cordwood on the steep slopes was not thrown down.

At Coast there was little sign of destruction by the earthquake, and nothing could be learned. At Bonnie Doon, tho the shock was appreciable, no clocks were reported stopt and nothing was thrown from shelves.

(B. Bryan.)—On the road thru Bonnie Doon the shock was uniformly light; chimneys were unharmed, plaster was intact, clocks did not stop, and even the milk had not spilt from the pans. People did not run outdoors. A top-heavy and rickety pigeon-house did not fall over, tho shaken considerably.

Down Laguna Creek to Coast, and up the trail east of Coja Creek to the asphalt beds, similar effects were noted. Near the latter spot, however, the shock appeared to have been somewhat stronger; small objects had fallen, milk spilt, and even one chimney was thrown down, while people were frightened enough to get out of the buildings.

From the asphalt beds as far east as the point 52, map No. 22, the observer found no one to question; but the shake had been so moderate as to leave no visible signs except where some cordwood had broken its end-stakes and rolled down at the ends. At the houses just south of this point, chimneys and plaster of 2-story structures were not damaged; only lamp-chimneys and such articles fell and broke. It was reported that at one house in the valley fruit-cans had been thrown from shelves.

(R. Collom.)—At the Wilder dairy, on the Santa Cruz-Pescadero road, 2 miles west of Santa Cruz near Meder Creek, the damage done by the shock was in the form of broken chimneys and cracked plaster in the houses. On the road 0.5 mile west of the dairy, the force of the shock broke an 8-inch water main.

A general examination of the country along the coast, as opened up by the Pescadero stage road, shows the damage in these parts to be confined mostly to broken chimneys and cracked plaster in the houses. Only in the case of buildings with very poor foundations was any of the superstructure destroyed.

(G. A. Waring.)—At Wilder's dairy it was said that the shock seemed to come southward down the gulch, preceded by a rumbling from the same direction. Other places on the terrace-land near the shore west of Santa Cruz were not so badly shaken.

Santa Cruz (B. Bryan).—Entering the city of Santa Cruz from the west, the first chimneys down were only about 0.5 mile from the San Lorenzo River, increasing in number as one came into the town; yet many of the better-built chimneys, even on 2-story and 3-story buildings, were not thrown down. In the eastern part of Santa Cruz, some chimneys on both 1-story and 2-story houses fell, and some stood. In some cases plaster was cracked, but in no case where enquiry was made had much fallen. Some small objects fell in every instance.

(R. Collom.)—The shock was strong, but no lives were lost. The court-house roofs and towers were wrecked, many brick chimneys were down, and communication with other towns was entirely cut off by the breaking of telephone and telegraph wires. Many buildings had their walls shaken down.

At the north end of the bridge crossing the San Lorenzo River, at Third Street, there were 4 fissures running practically parallel and almost due east and west. These fissures are about 700 yards in length, and vary in width from 2 to 8 inches. They run thru an apple orchard and are in sandy soil, the softness of the land near the river-bed being apparently responsible for their presence. The river at this place runs about east.

In going thru the town of Santa Cruz in the direction of Boulder Creek, a fissure at the intersection of Bulkhead and River Streets was noticed. This fissure was about

1.5 inches wide and ran east and west. The 90-foot brick smoke-stack of the San Lorenzo tannery, which is about 18 feet in diameter at the base, was unharmed by the shock. It is said that as far as was observed, there was no change in the appearance of the sea-level at Santa Cruz; nor was there any damage done by the sea, nor any unusually large waves at the time of the shock.

At the Southern Pacific bridge, crossing the San Lorenzo River, there is a network of fissures varying from 2 to 15 inches in width, running thru the sandy soil. The direction of the main fissures is east and west, and they are on the south side of the river, which is nearest the bay. The ground has settled about 10 inches from the abutments and piers of the bridge. The depth of the fissures was indeterminable, as they had filled with sand. At Santa Cruz the inhabitants reported that near Olive Springs, 12 miles north of Santa Cruz, a landslide demolished Loma Prieta Mill and killed 9 men.

(G. A. Waring.)—The city of Santa Cruz furnishes excellent evidence of the effect of soil formation on the intensity of the earthquake shock. On the high ground in Garfield Park, and also in the northwest part of the city, only about one-fourth of the chimneys fell and a little plastering was cracked; while in the lower ground near the business section several brick and stone buildings were partly shaken down. The San Lorenzo River was churned into foam, the banks cracking and settling several inches; and sand, said to have come from a depth of 100 feet, was forced up in several places. The bed of the river is also said to have sunk several inches, and the current to be slower than before. A 6-inch water-main, running east and west across the river at the covered bridge, was broken at each end of the bridge and moved 5.5 inches eastward. A man out of doors, facing south, was thrown east, then in the opposite direction. A eucalyptus grove south of him swayed violently east and west.

Along the beach the shock seems to have been less severe. The running engines of the power-plant at the Casino were unaffected. Things were thrown mostly from the west wall in a curio store on the beach. The wharfinger says he heard a rumble before the shock, coming from the southeastward; and saw the seismic wave traveling shoreward, causing a great rattling and crashing when it struck the town. Two distinct periods of vibration were felt, the latter being the harder. There was very little surf, the water looking like that in a tub when jarred. A safe in the wharf office rolled 3 feet eastward against the counter, then back again hard against the wall. The wharf, extending southeast, seemed to pitch lengthwise. Mr. W. R. Springer, jeweler, reports that out of 25 clocks repaired by him, which had been injured by the shock, 20 had their pendulums thrown off.

At the Santa Cruz light-house, a noise as of a wagon crossing a bridge preceded every quake. The motion seemed vertical as well as horizontal, for the glass globe over the lamp was jarred out and broken. In the curio-store at Vue de l'Eau, nothing on the lower floor was disturbed and only a few vases and pieces of bric-à-brac on the second floor were displaced. The shock seemed to come from the south. No effect on the surf was noticed.

(R. Collom.)—Going north from Santa Cruz, a small fissure ran northwest and southeast on the Boulder Creek road, about 0.75 mile northwest of the California Powder Works. Along the lower end of this road were several small and unimportant landslides. In general, the shock in this region does not seem to have been as severe as it was farther north.

Road into Scott Valley (B. Bryan). — Following the road from Santa Cruz into Scott Valley, at a summer hotel the chimneys were cracked all the way down, but were still standing; light objects on the first floor were moved, and bureaus on the second floor slid a foot or so. A 1-story frame house (at 53, map No. 22) was moved 4 feet or more, and a piano and other heavy objects were shoved across the room. The damage to the house was so serious that it was being torn down at the time of observation. A 4,000-gallon tank (at 54, map No. 22) was moved and burst open, letting out 2,000 gallons of water. At the house nearest it, the chimneys were cracked, but nothing inside had been disturbed except some bottles, and no plaster was cracked. Houses in Scott Valley had about this same amount of damage; chimneys were sometimes cracked but were still standing, and plaster did not fall.

Miss Finette Locke, of Scott Valley, reports that a man was thrown to the ground by the shock, and when he arose could not walk because of the earth's motion. The vibration was northeast-southwest. Everybody was awakened; all clocks were stopt; plastering was extensively cracked; and all chimneys were broken. About a mile north some chimneys fell, and in one house 4 dozen jars of fruit were thrown from shelves. Landslides and cracks are reported between Scott Valley and Felton, and the dam across a small lake was cracked. A statuette and a vase fell to the northeast. The largest chimney moved 2 inches to the northeast. The entire width of the road to the southwest of the small lake was splasht with water thrown out of the lake. Long billows on the lake extended northwest and southeast. In an 8-foot trough orientated east and west water was caused to sway back and forth, but not parallel to the sides of the trough. A neighbor who was awake heard a roaring noise in the northeast. Much milk and cream was thrown out of pans.

Going from Scott Valley toward the town of Felton, the shock appeared to grow constantly lighter; some people did not even get out of bed.

Felton. — In this village the shock was apparently lighter than at either Boulder Creek or Ben Lomond. At Zayante, some cordwood and some finer split wood, piled 8 feet high, was not shaken down, tho some of it was said to have been disturbed.

(R. Collom.)—The shock was only moderately strong. The damage consisted of the destruction of brick chimneys. Earthquake effects at this point are shown only by the damage to artificial structures.

Pescadero to Butano Creek (H. W. Bell). — In the town of Pescadero the shock was heavy; all but 3 brick chimneys fell, and but few buildings were otherwise damaged. Plastering was knocked from the walls in most of the houses, and church bells were rung. All the water-tanks observed were still standing, and none of the churches had lost their steeples, tho one church was cracked open. Cracks were visible in the streets. One man walking eastward along the road near Pescadero was thrown flat on his chest by the first shock, but jumped up and braced himself in this direction, and was then thrown southward. Cracks in the road also appeared, and dust spurted up. Several people were nauseated by the motion and some said that a noise as of a wind preceded the shock.

Going eastward from Pescadero, a small crack 30 feet long, with an east and west strike, was observed. In an orchard near by there were several cracks, the widest one measuring 8 inches, with a vertical displacement of 1 foot. About 2 miles east of the town, on the north bank of Pescadero Creek, a landslide in the shape of a half-moon, its axis lying N. 23° W., had slipt down toward the bed of the stream. The greatest vertical displacement at the top of the slide was 15 feet; the distance from its apex to the road about 85 feet; and the span from end to end along the road about 220 feet. No solid rock was exposed by the slide. The road had dropt 6 feet at the south end, and 8 feet at the north. Only a few cracks appeared on the surface of the part which had slipt. The creek lying directly below the road had apparently received very little soil from the landslide.

Along the stretch of road between this slide and the town of Pescadero, there were few cracks in the road and the houses were in good condition. The only brick chimney seen was down. The intensity was apparently the same as in the village, and continued the same along the road leading southeast toward Butano Creek. A 1-inch crack at the first fork of the road a mile from the town of Pescadero extended north and south for about 50 feet, and a farm house a mile farther down the road was nearly shaken off its foundations. Dishes fell from the shelves in this house, and water oozed out of level ground near by.

(G. A. Waring.)—On Butano Creek there were slight cracks in the road, and the streams were muddy. People said the shock was felt very distinctly, and dishes generally fell. The houses were all light, low buildings, and were not damaged. At a sawmill a mile east up this creek, there was no damage; and altho the banks beside the road showed traces of caving, there were only slight cracks, the longest one being in the middle of the road above the creek, running N. 67° E. for a distance of about 50 feet.

Along the main road from Butano Creek to Little Butano Creek, then across by trail to Pigeon Point, the same effects were noticed. Near a house on the level creek bed of Little Butano Creek, 4 cracks averaging 3 inches in width and about 20 feet in length ran N. 33° E. The only crack noticed along the trail toward the coast was 1 mile northwest of the place where Little Butano Creek turns from southwest to northwest, and was about the same length, but ran N. 3° W.

Pomponio Creek road (F. Lane). — On the Pomponio Creek road, chimneys were shaken but not destroyed. A big slide above the last house forced the observer to leave the road and take the trail, which rejoins the road a half mile farther on.

Four miles from the town of Pescadero, on the east side of a bridge over Pescadero Creek, the ground had sunk 2 inches and the aperture filled by the land sliding. A mile nearer the town, the road had dropt 5 feet, but had been filled by a big slide. A house at this point was quite intact, but the chicken-house near it was carried down and partly buried by the landslide. On Eues Creek, near its junction with Pescadero Creek, a hillside had started to slide and apparently needed only to become rain-soaked to continue the slipping. Wherever there were buildings in this region, no damage had been done except to chimneys, which had fallen.

The Coast from Pigeon Point to Ano Nuevo Bay (H. W. Bell). — At Pigeon Point the brick light-house, 125 feet high, showed a slight crack all the way around inside, about 40 feet from the ground. This crack did not look dangerous. Another crack 20 feet higher up dated from December 17, 1904, the keeper explained. The base of the pedestal holding the lens was slightly cracked, but the lens was intact. In the houses near the light-house the damage was slight; brick chimneys had not fallen, tho slightly cracked, and the same was true of plastering. A mile west of the light-house a few slight cracks, with a direction of N. 28° W., were observed.

Leaving the coast road at the fork halfway between Pigeon Point and Franklin Point, and going northeast along Gazos Creek, then southerly to the crossing of Whitehouse Creek, then back again to the ocean road near Franklin Point, few traces of the shock were noticeable. A small landslip, 0.25 mile up the east side of the short creek which flows into Gazos, just west of the fork of the road which continues northwestward to Little Butano Creek, showed a 2-foot vertical displacement at the top, and the land had shoved into the road below. This slide measured 150 feet from its top to the road, and its width at the road was 100 feet.

Along this route from Gazos to Whitehouse Creek, 0.125 mile from Whitehouse Creek, at several farm houses brick chimneys were down, houses slightly moved on their foundations, dishes broken, and plastering cracked. A half mile northeast of the mouth of Whitehouse Creek the same kind of disturbance was found. The intensity was apparently uniform with that at Pescadero. At the Cascade ranch, 0.25 mile northwest of Greenoaks Creek, the shock was even stronger than on Whitehouse Creek. Cows were thrown off their feet, chimneys were down, the house cracked, and nearly all plastering fell off.

(H. W. Bell.) — It was reported here that along the Ocean Shore construction work near Bolsa Point, a concrete pipe 24 inches in diameter and 6 inches thick, embedded in clay, had been cracked by the shock. The keeper of the Ano Nuevo light-house says a distinct rumbling preceded the shock, which came at first rather gently, followed by a hard, confusing shake. A brick chimney in the house near by was cracked and twisted 0.75 inch out of place, but the new tile and concrete building was unhurt. The ocean became no rougher, but had a peculiar greenish hue for several days after the shock. At Pigeon Point the shock was less severe, and little damage was done to the buildings, altho cracks in the light-house, caused by a former quake, were opened somewhat wider.

Following the road from the Cascade Ranch across toward Ano Nuevo Bay, the intensity seems to have decreased. At a house 0.75 mile southeast of where the coast road crosses Greenoaks Creek, a few dishes fell; plastering was but slightly cracked, and a water-tank stood. Half a mile north of the mouth of Ano Nuevo Creek, the brick chimney was knocked from a house, plaster was cracked, and cattle were caused to stagger. Half a mile southeast of where the main road crosses Finney Creek, a ledge of shale had been knocked into the gulch. The largest piece which fell had an unbroken surface of about 4 square feet. The almost horizontal edges of shale beds near a house at this point were knocked down. A long, narrow landslide above a house 0.75 mile northeast of the mouth of Waddell Creek had landed against the end of the house, taking out a strip of earth below a spring and causing a good supply of water to issue forth. This slide appeared to be partly due to the large amount of water present. At the house the chimney was cracked, but dishes did not fall from their places.

Turning north by a trail opposite Greyhound Rock, evidences of about the same intensity were found. Dead trees had fallen here and there, but in no uniform direction.

LOS GATOS TO SAN JUAN.

Los Gatos, Santa Clara County (I. H. Snyder). — Los Gatos, population 1,900, is partly on a mountain slope and foot-hills, and partly on river deposit. It is surrounded by hills on three sides. Los Gatos Creek runs thru the center of the town from south to north. The earthquake shock was violent, but apparently not so severe as in the central portion of the valley. Nearly all business houses were damaged, and about one-third of the plate glass fronts were broken. Much plaster fell both in Los Gatos and in the surrounding country. Chimneys fell in many different directions, and nearly half of the damaged chimneys left standing were twisted. About 80 per cent of all the chimneys were destroyed or damaged. Brick fronts were nearly all cracked, and one fell out. There were about a dozen upheavals of sidewalks, mostly on north and south streets. Grocers and druggists lost quite heavily in breakable goods.

The direction of the shock seemed to be in general north and south, altho there were certainly severe vibrations from nearly all points of the compass, while some persons are certain that there was a vertical motion, especially near the beginning. After the shock was over, our chandelier was still swinging violently north and south; a near neighbor's lamp swung in the same way; another hanging lamp 0.5 mile west swung northeast and southwest. East and west shelving in stores suffered rather the most, tho a store in East Los Gatos, with shelves north and south, suffered fully as much as any.

Of the 3 pianos seen in Los Gatos that were moved, 2 went to the south about 3 feet and one moved east the same distance. A small seismograph made several years ago was in working order, but there was no record, the needle having been thrown off by the extreme movement.

Mr. Lund, of Los Gatos, was one of the few people outside when the shock came. He is positive the premonitory roar came from the south and traveled to the north.

Mr. Dan Pickering, living about a mile south of Santa Clara, on the Santa Clara and Los Gatos road, was standing outside his barn when he heard the sound, which he compares to a stampede of cattle coming from the southeast. His tank and wind-mill fell diagonally across the foundation to the northwest, after swaying heavily three times; first to the northwest, then to the southeast, and finally to the northwest. He states that the ground rose and fell in waves a foot high. Others report that the orchards seemed to be agitated by a wave-like motion.

On the ranch of Dr. Tevis, about a mile from Alma Station, where the land is rolling and wooded, the ground was fissured and the bottom of an artificial lake was upheaved. (Plate 139c, D.) The cracks and fissures, of which there are many, run mostly north and south, and vary in length up to 100 feet, and in width from 0.5 inch or less to 20 inches. While a good many of the openings were parallel to the slopes and were caused by the ground starting to slide, others crost the roads and could be traced some distance up the banks. A board fence was splintered where it crost a fissure. The upheaval of the lake was caused by a closing together of the sides, shown by the heaving up of parts of the retaining dam at the lower end of the lake. The rise of the bottom is roughly 10 feet.

Three of the large cemeteries of the Santa Clara Valley were visited. In the Los Gatos Cemetery, on the New Almaden road, no monuments were thrown. In the Protestant Cemetery, 0.75 mile southwest of Santa Clara, 31 monuments were thrown down and mostly broken. Of these 10 fell to the south. In the Catholic Cemetery, 0.25 mile nearer Santa Clara, 26 monuments fell, of which 10 fell to the south. The direction of the fall of monuments in these two cemeteries is here tabulated:

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Total
Protestant . .	3		7[1]	1	10	1	5	4	31
Catholic . . .	5	1	6	2	10	1	1		26

[1] Of these, 4 fell from pedestals which leaned to the east.

In the Catholic Cemetery three monuments were turned on their bases, two clockwise and one counter-clockwise.

The Santa Clara city water-tower, with large tanks on top, fell to the southwest.

(F. H. McCullogh.)—I was in bed in Los Gatos and was awakened by the shock, which seemed to be a violent but irregular shaking back and forth in a northeast-southwest direction, altho objects were overturned in an easterly or southeasterly direction. A double bed on a polished floor rolled 4 feet from its position. One heavy marble clock was thrown off its shelf. Ornaments and bric-à-brac were thrown down. Two tables were turned upside down. Plastering was cracked. Chimneys were cracked above roof, but not thrown. In the town I could hear of only one chimney which was uninjured; 90 per cent of all chimneys were thrown down. Water in a reservoir 30 feet in diameter and 10 feet deep was thrown out so as to lower the level of the water nearly 2 feet.

Lexington (H. R. Johnson). — At the Lexington saloon, 3 miles south of Los Gatos, very little damage was done.

At the Averill place, 1.5 miles west of Wright's Station, a water-tank was moved a foot toward the south. A piece of board several feet long, which was leaning against the tank-house before the shock, was said to have been found wedged between the bottom of the tank-house and the foundation. This would necessitate a lifting of the tank-house in a vertical direction on that side, which might have been accomplished by the tank-house rocking from side to side.

Summit Hotel (H. R. Johnson). — At Summit, a summer resort, the new hotel and several small cottages were all thrown toward the north. The main fault fracture is about 500 feet northeast of the hotel, and a secondary crack close to it had a downthrow of from 5 to 7 feet on the north or downhill side. The crack was about 4 feet wide here, and the line of fracture was parallel with the direction of the ridge. The Summit school-house was dropt 4 feet downhill from its original position toward the northeast. In the vicinity of Summit several redwood trees were snapt off.

Just north of Wright's Station, on the west bank of Los Gatos Creek, there was a landslide 0.5 mile wide which had slid into the creek and dammed it. The top of this slide was near the Summit school-house and was close to the main fault-line. The Hotel de Redwood was destroyed by the shock.

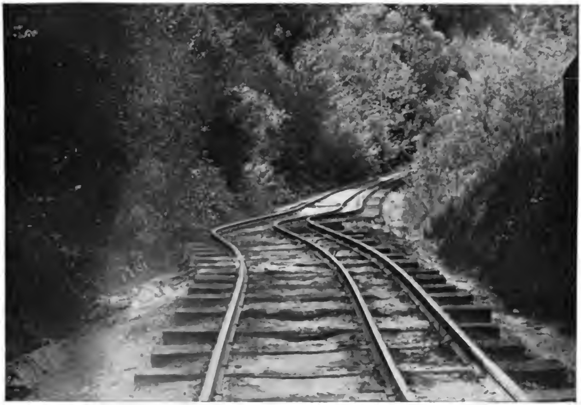
Wright Station (Miss F. C. Beecher). — Miss Beecher's home is on Loma Prieta Avenue, on the county line, 1.5 miles in an air-line from Wright's Station. The house stands on a ridge at an elevation of 1,700 feet. There were 2 maxima in the shock, of about equal intensity. The movement in the first was from south-southwest to north-northeast. All light objects were thrown down. Furniture against south walls was thrown down or moved out; objects against other walls were not moved as much. A small square piano which stood a few inches from a northeast wall ran back against the wall to the north with sufficient violence to break a knob off one leg. It then moved back to its original position, then 5 inches west. Then the two legs to the north jumped 6 inches south. These movements were determined by the marks upon the floor. A wash-basin, and a pitcher full of water, in an upstairs room, were thrown south, and the basin was found with the pitcher standing in it, uninjured but empty. A table in the middle of the same room fell to the north. A piano in a neighboring house, a heavy upright, was moved across the room to the northeast.

All brick chimneys on the ridge fell, mostly to the north. Trees at the foot of the ridge were bent over to the north-northeast. Half a mile to the northwest of the house, a fissure 2 feet wide appeared, from which bad-smelling gas emanated. The fissure runs from north to south, and the earth was piled up on the west side from 2 to 4 feet high across the road. On Highland, a mile to the west, a fissure 5 feet wide was opened at an altitude of 2,500 feet. A building standing close to a fissure was entirely uninjured, while others a little farther off were wrecked and one collapsed. Most good buildings in a belt 0.5 mile west of the house were wrecked, while barns and shaky buildings stood. About 1.5 miles west, a house split open. Gulches appear to have been contracted, as the bridges crossing them show that they were squeezed. The banks of Burrell Creek appear to have approached each other, so that the creek has become very much narrowed. Water-pipes were broken and twisted, and filled with dirt. Water was thrown out of tanks, but the tanks were not overthrown.

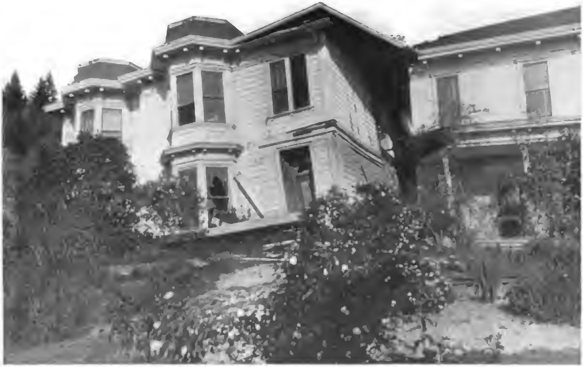
During the shock the waves appeared to oscillate in a north and south direction at first. There were at least 26 shocks during the first 26 hours after the main shock.

Burrell School (H. R. Johnson). — Near the Burrell school-house, 1.5 miles southeast of Wright Station, a crack extends across the road by a blacksmith shop and shows a downthrow of 4 feet on the northeast. The blacksmith said there was a strong odor of sulfur for 5 or 10 minutes after the shock. A well near by has had sulfur in the water for a number of years.

Morrell Ranch (H. R. Johnson).—The Morrell ranch is located 1 mile south of Wright's Station and is on the line of the fault. The house itself was built exactly upon a fissure, which opened up under the house at the time of the earthquake. The house was completely wrecked, being torn in two pieces and thrown from its foundation. (Plate 107B.) There was an apparent downthrow upon the northeast side of the fault, as seen in the orchard; but under the house the vertical movement was not so apparent. An especially strongly constructed wine cellar built into the side hill had the upper portion thrown 3 feet northeast, directly away from the fault-line. After the shock this upper portion



A. Shortening of railroad track between Los Gatos and Santa Cruz. G. A. W.



B. The Morrell house, near Wright Station. G. A. W.

of the house was left resting upon the wine tuns, and not upon its original upright supports (fig. 56). The fence and road near the house were crost by the fault and showed an offset which indicated a relative movement of the southwest side toward the southeast (plate 64B). One fence was broken apart, but the other was merely bowed, due probably to the resistance and drag of soil occasioned by a well-packed roadbed. The fruit-tree rows which crost the fault-line at approximate right angles were put out of alinement.

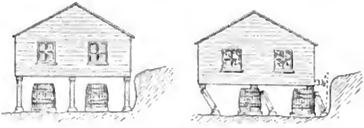


Fig. 56. — Section thru winery at Morrell ranch before and after the shock.

A feature associated with the movement of soil along the fault-line is shown in the accompanying sketch, fig. 57. The "splintering" of the main fracture raised a long, low ridge across which a creek had been forced to cut its way thru a vertical distance of 1.5 feet to get down to its original level.

Between Wright's and Alma the railway track was buckled. (See plate 107A.)

(D. S. Jordan.)—At Morrell's ranch, about 4 miles above Wright's, a large 2-story house with a wing stood on the slope of a hill. The east side of the house was much higher above the ground than the west, and stood on wooden piers about 7 feet high. The earthquake crack past thru this ranch, a branch of it going under the house. The main body of the house was thrown to the east, away from the crack, the ground there slumping several feet and the house being almost totally wrecked. All thru the orchard the rows of trees are shifted about 6 feet, those on the east side being farther north, and the east side, which is downhill, seems to have fallen. The crack is largely open and in one place is filled with water. This should be attributed to slumping. A little farther on, the crack passes thru a grassy hill on which there is no slumping. The Morrells say that this hill has been raised. What appears to be the fact is that the east side of the hill overrides the other. The whole top of the hill is more or less cracked for a width of about 10 feet. The east side is a little higher than the west side, and it looks as tho the hill had been shoved together and raised, the east side overriding. About 1 mile beyond Morrell's house, at the end of the ranch, there is a blacksmith shop, and the road is crost by the crack. Here there is a break of 3 or 4 feet like a waterfall, the east side being the lower; but this is part, I take it, of the general slumping of the east side of the crack

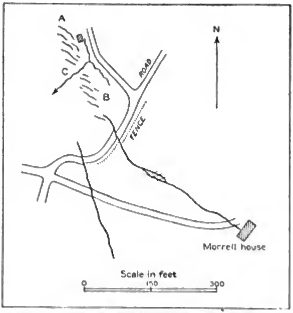


Fig. 57. — Displacement on auxiliary crack, Morrell ranch.

where it stands near the ravine above Wright. Morrell's place is right over the Wright tunnel, the tunnel and the rocks near by being of finely broken rock and very much subject to slides and other breaks. At Freely's place, 4 or 5 miles north of Morrell's, some 15 acres of woodland have slid into Los Gatos Creek, making a large pond. There are many other slides in the neighborhood and many broken trees. Farther on, the crack goes into Hinkley's Gulch, in which the Loma Prieta Mills are situated, and which are buried under the slides. The slides which obliterated Fern Gulch at Skyland do not seem to have come from the crack, but seem to lie to the west of the crack.

About four miles south of Wright Station (Mr. L. E. Davidson). — I was camping in the Santa Cruz Mountains. My attention was first arrested by a slight rumbling noise; then the house trembled for 4 or 5 seconds, and this was followed by a heavy rolling motion almost east and west. A heavy trembling came again for several seconds, then the heavy shock that threw down the chimneys. Tables and even chairs were upset. This must have lasted about 4 seconds; it then gradually died away. The whole time must have been all of half a minute. During the day several slight shocks were felt; about 2^h and 2^h 30^m P. M., two rather heavy shocks came.

The ridge on which we camped was full of cracks, ranging up to 2 and 3 feet in width, and in length from a few rods to 0.25 mile, all trending west of north to northwest. All chimneys on this ridge were thrown down; several houses were completely wrecked; branches were broken from the trees, while many of the trees broke in two and others were uprooted. The canyon south of us was filled with landslides. In this canyon the stratification of the rocks is plainly shown. The strike is northwest-southeast and the dip is almost vertical. The cracks coincide in direction with the strike of the strata. Cold water was flowing from some of the cracks. I obtained a small bottle of crude oil from Mr. Sutton, which he said was dipt up from the ground on his neighbor's ranch, several hundred gallons of oil having run out of the ground since the earthquake, where there had been no sign of oil before.

Skyland, Santa Cruz County (T. Wightman). — Mr. Wightman's bed traveled across the room to the south, and he was under the impression that the house was falling to the south. Some houses in the neighborhood fell completely, and some collapsed on their foundations. The two chimneys of his house were thrown, one coming through the roof. Some pictures hanging on east walls were turned with their faces to the wall. Large landslides occurred in the neighborhood.

Soquel, Santa Cruz County (Miss M. E. Baker). — The house is on the first high bench above the stream in Soquel Valley, with high hills to the north and the east. At the first movement of the earthquake, chimneys were thrown to the south; at the second, mantel ornaments, books in the library, fruit jars in the pantry, etc., were thrown toward the north. Some houses in the vicinity had chimneys and objects partly turned around. There were two maxima in the shock, the first being the stronger, and the direction of movement was from north to south. In the second part of the shock the movement seemed to be a twisting one.

Chittenden (G. A. Waring). — At Chittenden Station evidence of a most violent disturbance was found. The cottage of the foreman was moved 5 inches westward; an upright piano was thrown northwestward upon its back, and electric drop-lights swung so as to break against the ceiling. A large frame dairy building on underpinning was moved 3 feet northward, as was a smaller building. The oil in a large tank was thrown southeastward, badly bending the tank and smashing the protecting shed. (See fig. 58.) The railroad office was not moved from its foundations, but the porch roof was jerked nearly off and a 1,000-pound safe was thrown southeastward upon its back. Three freight cars on the side-track, loaded with beans, were tipt over to the northeastward. At the time of the shock a north-bound freight train was running at about 30 miles an hour, a short distance south of the bridge over the Pajaro. About 10 cars in the middle of the train were thrown off on both sides of the track. The track at the southern end of the Pajaro bridge sank from 2 to 4 feet for a distance of 150 yards, and between Chittenden and the bridge the track was bent in an S-shaped curve in several places. The concrete piers of the bridge were cracked, and the granite cappings shifted as before noticed. (See plate 65B and fig. 43.) There is much sulfur, oil, gas, and water in the hills here. A marked increase was noted in the flow of oil and water, and more gas and sulfur became associated with them. It is said that since the earthquake 16 years ago small shocks have been felt each spring, often severe enough to crack chimneys, and a deep well becomes muddy 2 or 3 days before these occur.

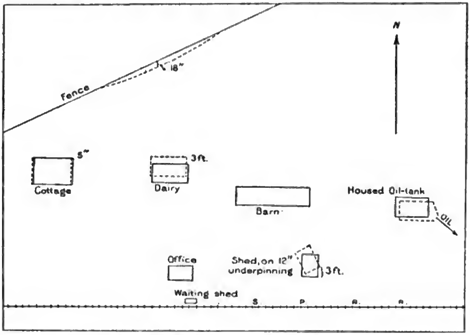


FIG. 58. — Displacement of buildings at Chittenden.

Fifty-two distinct shocks were felt during the day of April 18, and 32 that night. From 1 to 4 shocks were felt every day thereafter up to May 16, and from 2 to 5 occurred every night. Two miles north of San Juan, Mr. Canfield's house, at the foot of the hills 0.5 mile east of the fault, was moved bodily 2 inches westward, and the chimneys were completely thrown down; but a house 150 yards west of the fault, altho considerably shaken, appears to show the shock to have been less severe on that side.

San Juan (G. A. Waring). — The town largely escaped by virtue of being on solid ground. A large inner wall at the San Juan Mission fell, but it was no doubt weak, as other parts of the building appear unhurt. Only one or two chimneys in this village fell, but in the bottom-land between San Juan and Hollister the condition of the houses indicates a heavier shock on the low ground.

SANTA CLARA VALLEY.

Information regarding the distribution of intensity in Santa Clara Valley has been contributed by a number of observers whose names are given with the paragraphs dealing with the respective localities reported upon by them.

Newark (F. E. Matthes). — Nearly all brick and tile chimneys in the village were broken off; the direction of throw varied. Plaster cracked and fell in quantities on the lower floors of hotels and several other buildings. There are no brick houses in the town; and most of the frame dwellings showed no effects of the shock. At the depot the water-tank fell, the supporting trestle being practically demolished. The track suffered a slight shifting in several places north of the village. Cracks opened in the ground in the vicinity of 2 small watercourses, but on a less extensive scale than that noted at Alvarado. Some of them crost the railroad track. In every case they emitted the same bluish sand (with the water) that had been found near the Alameda Sugar Mill. In one place, 1.5 miles northeast of the village, considerable water was still left standing in shallow ponds. According to neighboring ranchmen, these ponds had not existed prior to the earthquake.

Centerville (F. E. Matthes).—The amount of destruction here seems greater than in the neighboring towns, but this is in large measure due to the presence of a number of poorly constructed brick houses. All of these had suffered severely, the walls being in part thrown down. The bank building was more seriously damaged than most buildings, the walls being partly demolished and the roof having caved in. With very few exceptions all the brick and tile chimneys were broken off. Window panes broke in several stores. No cracks in the ground were found or reported. The direction of the shock was not agreed upon by the residents; according to some it was north-south, according to others east-west.

Mission San Jose (S. Ehrman). — Nearly all chimneys were thrown down, and plaster in houses cracked; the direction of the throw of chimneys and objects being chiefly from north to south. Some objects were rotated clockwise, and hanging objects were caused to swing.

Irvington (F. E. Matthes). — Destruction similar in degree to that at Centerville. Every brick house was more or less extensively damaged; portions of walls fell in some instances, and cracks in brickwork were common to all. The large brick and stone buildings of the Palmdale Winery suffered more severely than any, and large portions of them will have to be rebuilt entirely. Only a few chimneys were left standing in the village. Plaster cracked and fell in large flakes in several houses. The upper stories apparently suffered less than the lower floors.

Milpitas (F. E. Matthes). — Nearly all chimneys were here thrown down, a few, including a very short one on the depot, being left intact. There are no brick buildings in the village and the destruction seems insignificant. The hotel slipt on its foundations, but was almost repaired at the time of the visit. A small adobe house in the southern part of the village was fairly demolished; it was known to be an old and weak structure. A water-tank and wind-mill were thrown down, support and all, about a mile south of town. They fell to the south. Another tank, north of town, appears to have fallen to the west. Several other tanks in this neighborhood were found intact. Of the two bridges over Coyote Creek, the northern one suffered some damage by displacement of end supports. It was unsafe to travel over at the time of the visit. The southern bridge was found intact, the end supports showing signs of but small movement.

Agnews (F. E. Matthes).—The insane asylum, consisting of three tall and three minor brick buildings and some small frame structures, suffered very severely. Every one of the brick structures was damaged beyond repair and will have to be entirely rebuilt. The main buildings were long, 3-story brick structures oriented north and south, with large projecting bay windows at their north and south ends. These were destroyed, so that both buildings are open at their ends. The fall of these walls caused the caving in of the roof, and the sagging down in some places of the floors. Numerous lives were lost; in all 112 dead being found in the ruins. The administration building was partly wrecked by the fall of its tower, which crashed thru the roof and all the floors, carrying with it a number of people. In nearly all cases the north and south facing walls were thrown out, while the east and west facing walls were, as a rule, better preserved. The shock seems to have been north-south principally, judging from these data.

The tall brick chimney of the engine house (100 feet high) broke off 20 feet above the ground and fell in a northeasterly direction, without touching any other structure. Frequently window-panes remained unbroken in the lower parts of walls whose upper parts had been completely demolished. (See plate 108A, B.)

The extent of the destruction is in some measure due to the use of weak mortar, the bricks having, as a rule, fallen separately rather than in aggregates. It is believed that well-built buildings would not have suffered such wholesale destruction as was witnessed here.

Alviso to Milpitas (G. F. Zoffman). — Evidences of the earthquake at Alviso are shown only by fallen chimneys and cornices and by cracked walls of the brick warehouses. No buildings were demolished and little serious damage of any kind was to be noted. From 1,500 to 2,000 feet west of the bridge over Coyote Creek, cracks cross the road in front of the Boot ranch-house, and several of them occur in the road leading to that house. (Plate 140B.) Some of these cracks are about 6 inches wide and have a general bearing of N. 43° W. Immediately after the earthquake, water flowed from some of them and brought up sand, which was heapt up about 6 inches high. The water ceased to flow after the second day.

Near the dwelling house on the Boot place, the ground settled 11 inches on the east side of the crack. The fissures past under the corner of the dwelling house and the building was partly thrown from its foundation. The cellar beneath it was filled with water to a depth of from 2 to 3 feet. There is a capped artesian well in the yard of this house, and about this well is a pool of water 12 feet across. The west side of the pool was lifted 1 foot higher than the east side, and fish were thrown out of the pool. A hundred feet east the fissures past under the barn, and the ground settled on the west side. Water flowed from cracks in the yard and piled up sand 6 inches high on both sides.

People living near Coyote Creek state that the water rose between 2 and 3 feet immediately after the earthquake; and up to April 26 the water in this stream had not returned to its normal level. At the bridge over Coyote Creek, on the Alviso-Milpitas road, the concrete abutments were thrust inward toward each other about 3 feet. A pile driven in the middle of the stream, which had been cut off below the water-level, was lifted about 2 feet and now rises above the water.

About 150 feet north of this bridge the banks of the stream cracked, the fissures running parallel with the channel and the land on the creek side sliding toward the stream. (Plate 140A.) West of the stream, in an adjoining field, water rising thru cracks built up many craterlets of sand. (Plate 143A.) Residents of the vicinity state that the water rose 3 or 4 inches above the tops of these craterlets while they were being formed, and that it ceased to flow toward the end of the second day after the earthquake.

In the road running northward along the west side of Coyote Creek from the bridge, many large cracks opened. Five hundred feet north of the bridge the cracks were 2.5 feet wide and 3 feet deep when the place was visited April 26. Farther north the cracks were very abundant, mostly parallel with the road, and some were 4 feet deep and 3 feet wide. A quarter of a mile north of the bridge, the whole road was shoved eastward into the channel of the creek, and with it a large number of willows and cottonwood trees that grew along the banks. Just south of this place the road was broken up badly for a distance of 300 feet. One of the largest cracks in the road was 5 feet wide, 6 feet deep, and more than 100 feet in length. The bearing of the fissures at this place was N. 23° W. For the most part the principal features were approximately parallel with Coyote Creek.

At Mrs. North Whitcomb's ranch, on the south side of the Alviso-Milpitas road, between Coyote Creek and Milpitas, the prune orchard was cracked and the ground shifted at several places. The ranch-house, of concrete with a wooden upper story, was cracked across the northwest corner and settled slightly on the northwest side. In the back yard were fissures 1 foot wide, running about N. 13° W., with a downthrow of 1 foot on the east side. Some of the prune trees in the orchard are 2 feet out of alinement, and some as much as 6 feet. The lateral displacement here shows a relative movement of the south side toward the east. Considerable sand was brought up by water flowing from the cracks in this orchard.

In the town of Milpitas all the chimneys were thrown down, as well as 3 frame buildings. The hotel fell from its underpinning and sank bodily about 3 feet. The streets near it were not disturbed.

Warm Springs (G. F. Zoffman). — The Warm Springs Hotel, a large 2-story building, was but slightly damaged, only a little plaster falling. No buildings were damaged, beyond the falling of two chimneys.

Milpitas-San Jose Road (G. F. Zoffman). — About 0.5 mile south of Milpitas, on the Milpitas-San Jose road, cracks were formed across the road. They did not, however, appear to have any definite direction, and were so small that no lateral movement was discernible. At the County Alms House, about 1 mile south of Milpitas, two chimneys were thrown down and considerable plaster fell. On the north side of the bridge which crosses Coyote River, on the San Jose-Milpitas road, some cracks were found but they were evidently caused by the sliding of the banks. The bridge was not damaged.

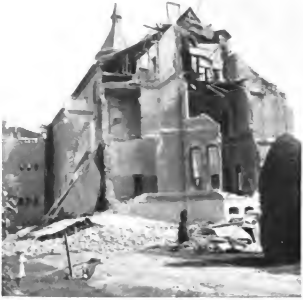
The damage in the section of country lying between Milpitas and San Jose was nearly uniform. About 90 per cent of the chimneys were thrown down and in all houses that were plastered considerable plaster fell. Articles in the houses were thrown over, and much water and milk was spilt, altho it does not appear to have been in any particular direction. Cracks like those which were observed in the ground on the Milpitas-Alviso road reappeared on both sides of the Coyote River at intervals all the way to San Jose. Altho they occur in a general north-south direction, it seems probable that their origin was due to the unstable condition of the alluvial deposits which underlie the valley.

Alum Rock Road (G. F. Zoffman). — Starting from San Jose and going toward Alum Rock, it was observed that the shock had decreased from an intensity of IX at San Jose to an intensity of VI at Alum Rock. No cracks were found between Coyote Creek and the mountains, but in the valley at least 90 per cent of the chimneys were thrown. At the mouth of the Alum Rock canyon, a count of the fallen chimneys revealed the fact that the percentage had dropt to 50. At Alum Rock no chimneys were damaged nor had any movable objects been overturned, altho the water in sulfur baths had splasht up about a foot on both sides.

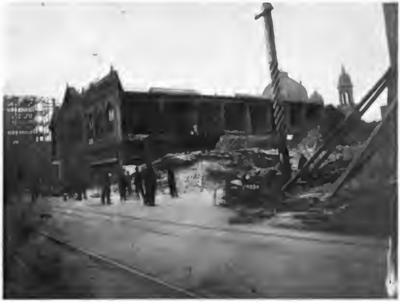
Calaveras Valley to Evergreen and vicinity (G. F. Zoffman). — Going from Milpitas toward the Calaveras Valley, chimneys were all thrown down on the flat lands between the village and the foot of the grade leading over the ridge to Calaveras Valley.

In Calaveras Valley all the brick chimneys were thrown down, tho there were only a few in this valley. No damage to houses is reported. Mr. Hadsell, in charge of the property of the Spring Valley Water Company, which has begun to construct a dam at the north end of the valley, states that there was no shifting of the strata in the tunnels, and that no damage had been done the property.

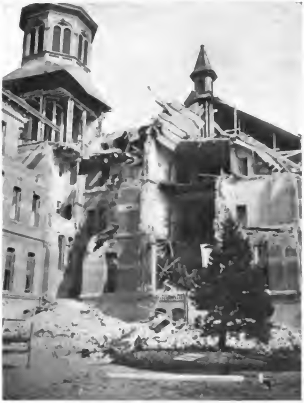
Between this place and the head of Alum Rock Canyon, the residents stated that cracks appeared across the road in several places; but altho this was in the proximity of the Calaveras Valley fault-line, which passes thru this region, it was not possible to verify their statements. Mr. Robert Ingleson, who lives in section 22, on the ridge east of Calaveras Valley, reports that the shock was not severe there. A long slender bottle standing on a table in his house fell over, but a lamp on the table was not upset.



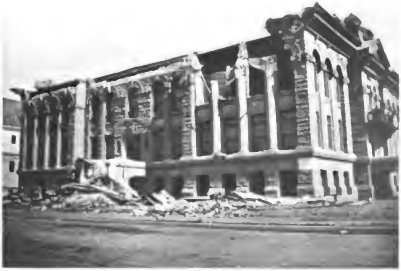
A. Agnew's Insane Asylum. North end of female wards. F. E. M.



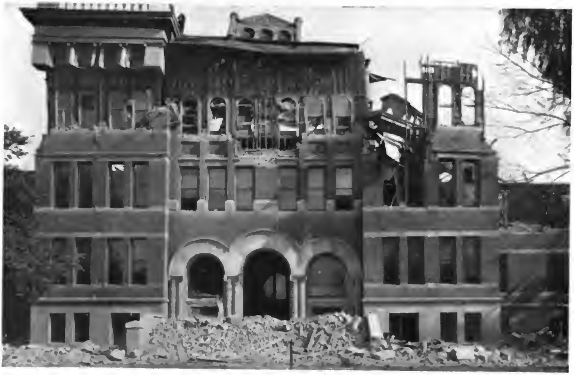
C. Phelan Building, San Jose.



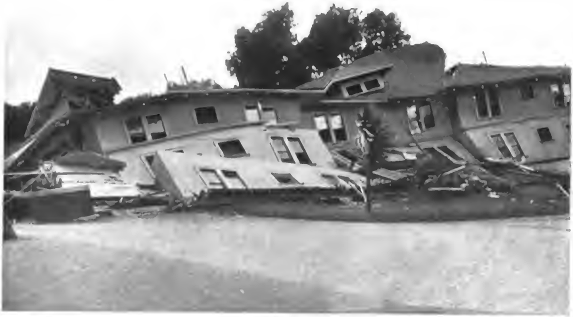
B. Agnew's Insane Asylum. North side. F. E. M.



D. Hall of Records, San Jose.



A. High-school, San Jose.



B. Hotel Vendome, Annex. San Jose.

Water in a horse-trough spilt out, and the trees waved as if there had been a wind. The earthquake consisted of two separate shocks, accompanied by a roaring sound that seemed to come from the north. Springs near his house became muddy after the shock and remained so for 2 or 3 days. The flow of the springs increased to about four times the usual amount.

Along the road down Penetencia Creek, a considerable amount of débris had slid into the road, in many places obstructing all travel except for pedestrians; but no evidence of cracks could be found.

In the region between Alum Rock and Evergreen, about 50 per cent of the chimneys were thrown down, but none of the buildings were materially damaged.

As the Santa Clara Valley was once more approached, the intensity of the shock perceptibly increased. At Evergreen, about 1.5 miles from the foot-hills, considerable damage was done; all the chimneys, all the road tanks, and nearly all of the wind-mills in the neighborhood fell. None of the houses were demolished, but some were shifted on their foundations.

(H. R. Johnson.)—The Pierce ranch-house, 3 miles southeast of Evergreen, was badly shaken; plaster and chimneys were down and much chinaware was broken. This house is on the gravel of the large alluvial cones which have been built out along the southwest face of the Monument Peak Range, where the stream debouches upon the plain. A water-tank fell northeast and southwest where the Tully road crosses the Coyote River 1.5 miles northeast of Oak Hill Cemetery.

At the Mayne ranch, 3 miles south of Oak Hill Cemetery, where the New Almaden Railroad crosses the Downer road, water from tanks and troughs was spilt in a northwest and southeast direction. To the west of the Mayne ranch, at the Downer ranch, a water-tank fell to the west. Mr. Downer said that milk in pans was spilt in the same direction.

At the Poncelet ranch-house, on Llagas Creek, 7 miles southwest of Madrone Station, only one chimney fell and no dishes were broken and no clocks stopt. This place is only 3.5 miles northeast of the fault-line and is situated directly upon rocks of the Franciscan series.

The Saunders ranch is 3.5 miles southwest of Madrone, on the Madrone road. The shock was quite heavy at this place; the chimneys were thrown down, dishes broken, and portions of what appeared to be quite solid and massive rock outcrops were thrown from the steep hills near the house. South of the Saunders place, 1.5 miles, a water-tank was thrown down.

Santa Clara (G. F. Zoffman).—Nearly all the brick chimneys were thrown down and most of the brick buildings were damaged. At Santa Clara College the rotary motion of objects was shown by the turning of statues in the chapel thru an angle of 130°. In the library of the same institution four marble statues, with square bases, fell in three different directions; one facing S. 87° W., another facing N. 87° E., fell toward each other, while the others, facing, respectively, N. 3° W., S. 3° E., fell N. 3° W. Professor Ricard, of the Science Department of the College, states that the vertical movement threw a wind-gage out of a socket a foot deep. This was the only evidence at the College of vertical motion.

Cemeteries (G. F. Zoffman). — A count was made of the number of tombstones thrown down in the Santa Clara Cemetery and the various directions in which they fell were noted. From these observations it seems that the shock was slightly more intense toward the easterly direction than toward the westerly. Twenty-five headstones were down and their respective directions of falling were, 3 N. 17° E.; 1 N. 32° E.; 1 N. 37° E.; 2 N. 62° E.; 1 N. 77° E.; 1 E. 17° S.; 1 S. 58° E.; 6 S. 28° E.; 3 S. 23° E.; 1 S. 3° E.; 1 S. 37° W.; 1 S. 42° W.; 1 N. 88° W.; 1 N. 73° W.; and 1 N. 13° W.

At Oak Hill Cemetery the larger percentage of tombstones fell in an easterly direction. Out of 34 monuments overthrown, 21 fell toward the east or nearly so; 6 toward the west or nearly so; and 1 toward the north or nearly so; 3 fell northeast, one fell northwest, 1 fell southeast, and 1 fell southwest. Out of 6 round monuments that were noted, 4 fell toward the east, 1 northwest, and 1 north. Since these could fall in one direction as quickly as another, it is evident that the greatest movement of the quake must have been toward the east at this particular place.

At the Catholic Cemetery, about halfway between San Jose and Alum Rock, only a few monuments were overturned; they fell as follows: 2 north, 3 south, 1 northwest, 2 east, 1 west, 1 southeast.

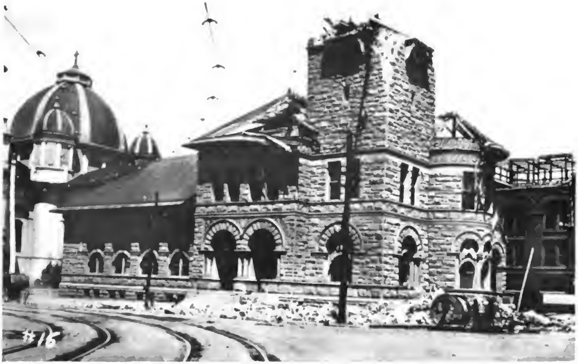
San Jose (G. F. Zoffman). — The earthquake threw down many brick and stone buildings (plates 108c, D, 109A, 110B, 111, 112, 113), and with the exception of 4 or 5, damaged all the rest of the brick buildings, more or less. (Plate 110A.) The damage done to frame houses was proportionately far less. Forty buildings were counted, however, that were thrown off their foundations and damaged to a greater or less extent. In many instances these buildings were completely demolished. (Plate 109B.) Numerous wind-mills and tanks capsized, while at least 95 per cent of the brick chimneys thruout the town fell. Movable objects, such as pianos, were in most cases wheeled out into the room, but there did not appear to be any general direction in their displacement. Water and mud in many instances are reported as having spurted from the artesian wells, but in a few days they resumed their normal condition. The plate-glass windows on the south side of First Street were cracked much more than those on the north side. This phenomenon was not noticeable on the other streets.

Data were obtained of the directions in which the chimneys fell thruout the town. After the data were collected and tabulated as shown below, it became evident that chimneys usually fell with the slant of the roofs.

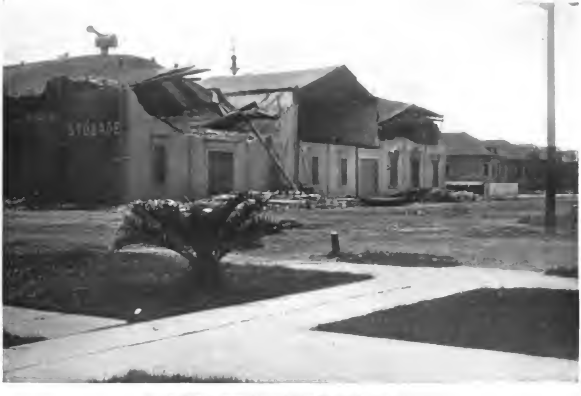
In order to group the directions in which chimneys fell, the circle was divided into 8 sectors, of 45 degrees each, starting from the bearing of First Street, namely N. 30° W. The general directions of these sectors are: N. 15° E.; S. 15° W.; S. 75° E.; N. 75° W.; N. 60° E.; N. 30° W.; S. 30° E.; and S. 60° W. Then the direction of the falling of a chimney was taken according to the sector toward which it fell. The streets in the main part of town run either parallel or at right angles to First Street. Since the bearing to First Street is N. 30° W., that of Santa Clara Street (at right angles to First) is N. 60° E. Generally the slant of the roofs of the houses that face these two streets will be N. 30° W., S. 30° E., N. 60° E., and S. 60° W., respectively. It was in these four general directions that the greatest number of chimneys were thrown over. The eight general directions are as shown on the following table:

Directions of throw of chimneys.

Directions.	On streets parallel or approximately parallel to Santa Clara Street and percentages of total number down on these streets whose bearing is N. 60° E.		On streets parallel or approximately parallel to First Street, and whose bearings are N. 30° 39′ 45″ W.		Total number of chimneys counted in San Jose and their directions of falling.	
	Out of 710 chimneys.	Percentage.	Out of 2000 chimneys.	Percentage.	Out of 2710 chimneys.	Percentage.
N. 15° E. . .	52	7.3	222	11.1	274	10.1
S. 15° W. . .	43	6.1	184	9.2	227	8.4
S. 75° E. . .	87	12.3	225	11.3	312	11.5
N. 75° W. . .	69	9.7	248	12.4	317	11.7
N. 60° E. . .	178	25.1	239	11.9	417	15.4
N. 30° W. . .	58	8.2	362	18.1	420	15.5
S. 30° E. . .	82	11.5	348	17.4	430	15.9
S. 60° W. . .	141	19.8	172	8.6	313	11.5

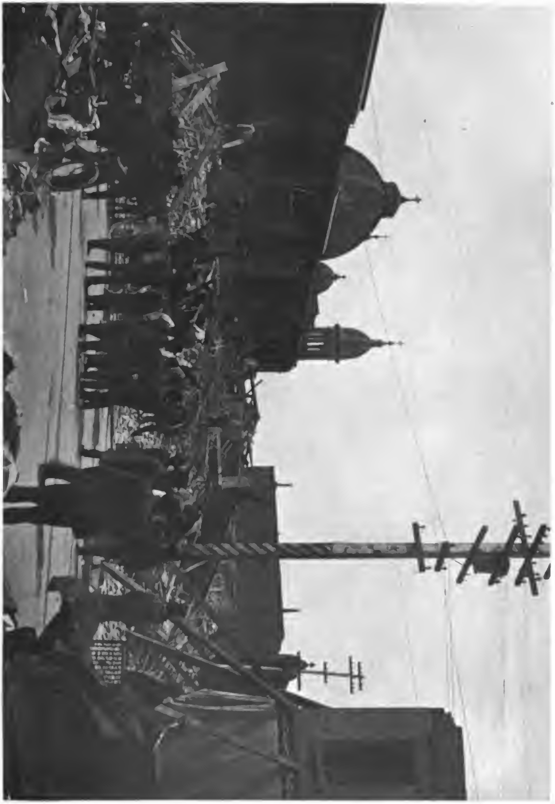


A. Post-office, San Jose.



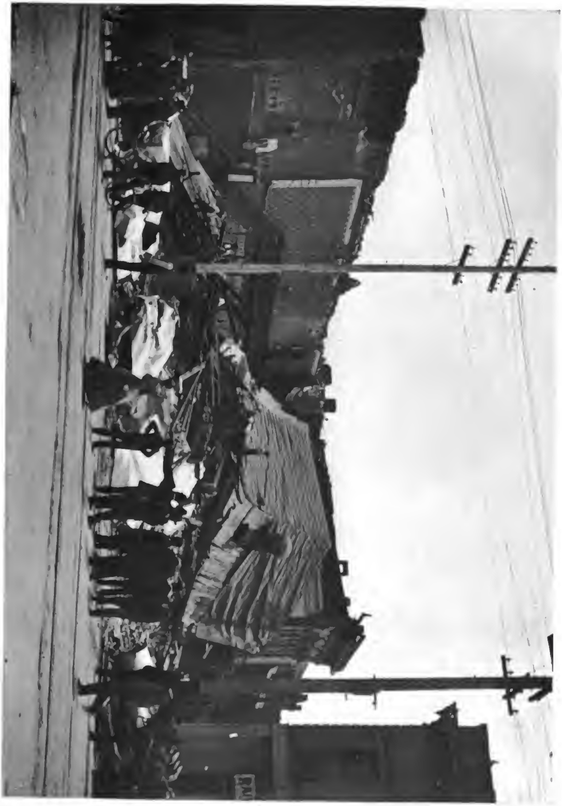
B. Box factory, corner Fifth and Julian Streets, San Jose. A. C. L.

PLATE III

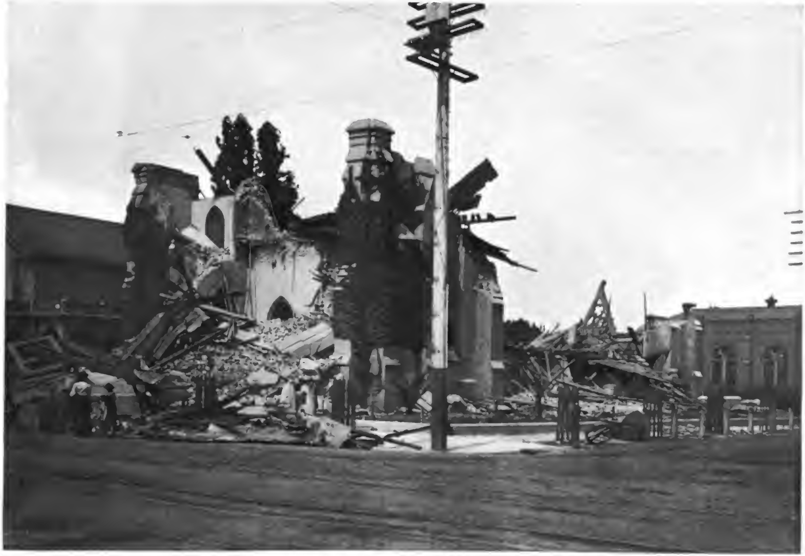


San Jose.

PLATE 112



San Jose.



San Jose.

(E. C. Jones.)—There was only one broken gas main in San Jose, caused by the high wall of the building falling over; the bricks penetrated thru the soft earth to the main and broke it. At the gas station, the brick retort house was very badly damaged. The north and south gable ends fell out. The brick work at all 4 corners loosened for about 10 feet down to where the roof trusses are anchored in the walls. The superheater of one of the gas-making machines settled on the south side so that it was 2 inches out of plumb. The weight of this machine is about 78 tons. Some of the cast-iron connections in the building were broken.

The purifying house, also of brick, was totally destroyed; all the walls and the roof collapsed, carrying the machinery to the ground and destroying it. The relief gas-holder was full of gas at the time of the earthquake and was badly damaged. Two of the cast-iron columns were broken off in several places; portions of the railing fell thru the crown of the gas-holder, permitting the gas to escape. The distributing holder was three-fourths full of gas at the time of the earthquake. The movement threw about 12 inches of the water out of the holder tank. The carriages on the lower section were all broken, these being of cast-iron. The upper carriages, made of wrought iron, were strained but not broken. Considering the violence of the disturbance at this point, it is surprising that the mains did not suffer more than they did; but the breaking off of pipes in the buildings and the crushing of meters under falling houses necessitated shutting off the gas thruout the city for 24 hours.

(W. S. Prosser, C. E.)—Over the San Jose area, as a whole, the wreckage seems to have been thrown in all directions; but in certain places some slight system appears. It seems clear that no statement as to direction, amount, or even duration of motion applies to more than a limited area. The only clear cases of rotary motion seen by me were two cases near my home, 2 miles northwest of the center of town. One tank-house turned exactly halfway round, as well as upside down, and one chimney turned about 4 inches, both in the direction of the hands of a clock. Both rotary and vertical motions were felt by many, however. About 500 yards from me is a square brick fence-post 7 feet high, of which 2 feet moved about 3 inches to the southeast (S. 44° E.); or rather, the bottom moved the reverse way. On Stevens Creek road, leading southwest from San Jose, 5 or 6 water-tanks on the roadside fell. One of these seemed thrown to the northeast, but others were twisted and scattered as tho by a mixture of all motions. In some places most of the buildings, perhaps, fell to the north or northwest. In Chinatown (north of San Jose) it was the north and south brick walls that fell. In San Jose most of the clocks on east and west walls did not stop, but many of those on north and south walls did; showing an east and west motion. The brick 7-foot wall around the yard of Nôtre Dame School in San Jose, on the northwest side, fell; but that on the south did not, altho it was cracked. The streets in the central part of San Jose run N. 60° E.

The amount of motion differs greatly. In many cases brick work seems to show a sharp blow of 2 inches; sometimes more. The inside east and west wall of the City Hall has a crack of 4 inches. The front of La Mott House (east and west) moved in some places 2 inches, in others 4 inches. The master clock in the Western Union Office (on the ground floor of a large brick building, and on the east and west wall) did not stop, but the pendulum struck both sides of its case many times and with great violence, battering off the varnish. It is long (probably beats seconds) and had to move about 4 inches more than usual in order to strike the case.

About 5 miles south of San Jose there were said to be two tubs of water on the ground a few hundred yards apart. No. 1 had most of the water splasht out, but No. 2 apparently had lost none. No. 2 is nearer the hills, and bedrock is nearer the surface. The oil tank at the corner of Stockton and Polhemus Streets, 1 mile northwest of San Jose, splasht over. Many water-tanks did the same.

Several good observers out of doors are positive that the noise of the quake came from the southeast and died away toward San Francisco. In the afternoon of the 18th, my wife heard the noise of a shock and called out before we felt the shock itself. The noise seemed to come from the south or southeast.

Many persons saw waves in the ground. Sifting out exaggerations, these appeared to be rather more than a foot in height. The best observer estimated the distance from crest to crest at 60 feet, others at much less; but I think the waves must have been greater, for there is no evidence in long brick walls showing any such vertical cracks as would have been produced by short waves.

Six miles southwest from San Jose, a good observer described the waves as parallel with certain tree-rows which are northeast and southwest, and stated that the waves moved from him at right angles to the line and toward San Francisco. Six miles northwest from San Jose, a man looking south saw the waves (which he thinks were east and west) coming toward him, and hence toward San Francisco. About the middle of the quake these were met by other waves, and the whole surface resembled hillocks, or cross-seas, while the tree-tops waved wildly. To the man southwest of San Jose, however, the tops of the trees were almost still, while the trunks waved sinuously. Near me is a piece of ground 10 by 30 feet, raised about 7 inches; while about 150 feet southeast of this is an area about a yard square which dropt 6 inches. Possibly these represent the crest and trough of an earth-wave.

I estimate the duration, I think closely, at between 50 and 60 seconds.

The wells of the vicinity seem to show slightly increased flow. One 80 to 100 feet deep has been a little roily since the quake, and one near San Jose was reported as having increased the day before the quake.

(M. Connell.) — On the farm of Mr. Fox, 3 miles north of San Jose, the water pipe of an artesian well was broken off 60 feet below the surface and carried by the heave of the land in a northwesterly direction 4 feet from its original position.

County road south of San Jose (H. R. Johnson). — At Schutzen Park, 2 miles southeast of San Jose, the shock was felt quite severely. The road house was badly shaken, but very little glassware was broken in the bar-room. A 12,000-gallon water-tank was shifted slightly on its foundations. At this place the first part of the shock was thought to be quite light and the second part heavy; the general motion was said to be from east to west. At the 5-mile house, farther southeast on this same road, there was hardly any damage reported. Even plaster in houses did not fall. There was also little damage at the house 0.5 mile southeast of the 5-mile house. The chimney did not fall, but dishes and lamp-shades were broken. The movement was thought to be northwest-southeast in direction.

It was stated by Mr. Russel, of Edenvale, that the shock was lighter there than at San Jose. A well-constructed brick building, which was built 3 years ago, had the roof loosened and the end walls were cracked. About 3.5 miles southeast of the 5-mile house at the Van Every ranch, a chimney fell, plaster on the first floor was badly cracked, and furniture slid around upon the floor. Water was spilt from a tank and a water-trough.

Just northwest of the 12-mile house, where the county road crosses to the Fisher ranch, there were cracks from 2 to 6 inches wide in the coarse gravelly bottom of the Coyote River. There was evidence of water having been ejected from these cracks, as there were heaps of clean, fine material surrounding small orifices. It was said at the ranch-house that muddy water came out of these openings following the shock. Half a mile southeast of Fisher's, a water-tank was down.

Half a mile south of the 15-mile house, the Barnhart ranch-house, which was set upon wooden underpinning, was thrown from its foundation, so that it rested directly upon the ground, 4 feet farther north than its proper place. An old barn and water-tank were uninjured at this same place.

A quarter of a mile south of the 15-mile house, on the county road, a water-tank was thrown down. Going 3 miles northeast from the 15-mile house, Webber's old ranch-house was visited. Here baled hay piled in a barn was shaken down and doors leaning against the house were thrown from their position. Water in both the creek (Coyote River) and a well was muddy after the shock.

(H. R. Johnson).—Going northeast thru San Felipe Valley to Smith Creek Hotel, hardly any evidence was seen of damage from the shock. At Smith Creek Hotel no china nor plaster was broken, but two chimneys were thrown down.

Los Gatos to Gilroy (G. A. Waring).—Near Meridian, 3 miles west of San Jose, several cottages were shifted from their foundations. All water-tanks on open frames fell, but those that were boarded in stood. The water became muddy in several wells. One lady reports seeing waves traveling southward along the driveway, and a man reports seeing a heavy wagon move 4 or 5 feet back and forth several times, along the driveway. The shock began violently and ended suddenly. The intensity diminished uniformly from Meridian toward Campbell. At Campbell, 68 per cent (51 out of 89) of the chimneys fell, but the plastering in the houses was not badly injured. From Campbell toward Los Gatos the intensity slightly increased. At Los Gatos 78 per cent (67 out of 86) of the chimneys fell. At the distillery 4 miles west of Los Gatos considerable damage was done. The second floor was moved about 18 inches toward the northeast, causing the wall to bow out on the northeast side. Many of the large vats holding 2,000 gallons were shaken off their supports and several were broken by the fall. The shock in Los Gatos, however, was not so sudden as to cause serious injury to brickwork or plastering. The business part of the town is built on 40 feet of gravel overlying shale. Only two stones in the Los Gatos Cemetery were shifted.

At Alma the shock was of about the same intensity as at Los Gatos. Milk in pans was nearly all thrown to the north and south. The Morrell house (see plate 107B), near Wright Station, is directly over the fault and suffered more than any other place in the vicinity of Wright Station, tho at least 5 other buildings between Patchin and Skyland were badly wrecked. Going from Los Gatos toward Edenvale, the shock was somewhat lighter than at Los Gatos, judging by the effect on chimneys, plastering, and movable objects; but at Edenvale it was a little stronger than at Los Gatos, as shown by the damage done to the large brick canning factory. All the walls were badly cracked and the tops of the walls fell. The top of the fire-wall above the roof was shaken down.

Continuing to the southwest thru Coyote, it was about the same as at Los Gatos, diminishing a little thru Madrone, Morgan Hill, and San Martin, where it had about the same intensity as at Los Gatos. Near Coyote a man reports having seen a northwest-southeast fence move in wave-like fashion, beginning at the southern end; and he heard a noise coming from the southeast and seeming to pass over him. Another man driving along the road near San Martin, heard a roar and his horse became frightened, before the shock came. Clouds of dust arose in the road and the creek near by was rendered muddy by the shock. At Morgan Hill about 64 per cent (18 out of 28) of the chimneys fell, and a 1-story concrete-block building was badly damaged, the whole front having fallen out. A 2-story reënforced concrete-block building was not damaged.

At Bucker, 3 miles north of Gilroy, the shock seems to have been about the same. The school building was badly damaged, and several windows were broken by the twisting of the frames. At Gilroy nearly every chimney fell, fire-walls of brick buildings were thrown down (plate 114A, B), and shelf goods were largely shaken down. In the Masons and Odd Fellows Cemetery, out of 120 stones over 3 feet tall, 31 fell. A cylindrical shaft fell north, and a square one fell south, but all the rest fell east or west, tho the tall slabs necessarily fell east or west because they faced east. Two marble shafts about 8 feet high were broken off halfway up, the lower part and base being unshifted. In the Catholic Cemetery 10 stones out of 67 fell.

In the hills between Los Gatos and Gilroy the shock seems to have been somewhat less severe. At the New Almaden mines, the tops of 2 brick furnace chimneys, about 50 feet tall, were broken off; but the furnaces were unharmed and the underground workings unaffected. About 70 per cent (16 out of 23) of the chimneys in the settlement here (Hacienda) were broken off. A loud noise like thunder is reported to have traveled northward down the canyon, distinctly preceding the shock. This has often been heard since, seemingly underfoot, even when no shock has been felt.

Southward from New Almaden thru the hills the houses on alluvial land suffered noticeably more than those on more solid ground. From Uvas westward to the summit, the intensity rapidly rose as the fault was approached. Two miles west of Uvas P.O., and half a mile east of the summit, an east-and-west stone wall, built of loose boulders, was thrown mostly northward; water was thrown from troughs toward the north; and all streams were muddy for 2 days after the shock, while in wet places there was a noticeable settling of the ground.

Southward from New Almaden along the eastern side of the valley, the shock uniformly lessened in its intensity thru Old Gilroy and San Felipe to Hollister. At San Felipe a large stone cheese factory was not damaged, except for a few cracks. The lake 0.5 mile west of the village was considerably stirred up, and water from a full road tank was thrown 60 feet across the road. A considerable rumble was heard all thru this region; one person says it came from the southeast, traveling down the valley; another says it came from the southwest.

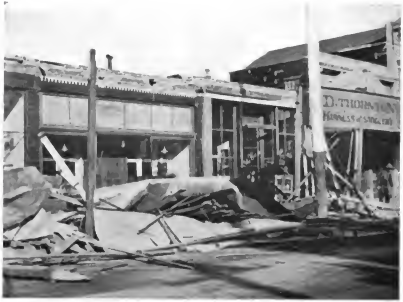
Along the railroad track from Gilroy to Sargent, nearing the fault, the intensity rose considerably, but the motion was a slow, swinging one. Water was all thrown from reservoirs, and trees swayed violently; but plastering and shelf goods suffered little. At Sargent all loose objects were thrown about, but no buildings were shifted.

(A. J. Champreux.)—About 90 per cent of the chimneys in Gilroy fell, the prevailing direction being east and west. No frame houses were thrown off their foundations. Brick walls were damaged at the top by the fall of 8 to 20 courses of brick. Most of the plastered houses suffered by the cracking of plaster. No cracks were found in roads or pavements. At the Cemetery, about 50 per cent of the monuments were overthrown. Of the fallen ones, 95 per cent were thrown in an east-west direction. All monuments overthrown had square bases.

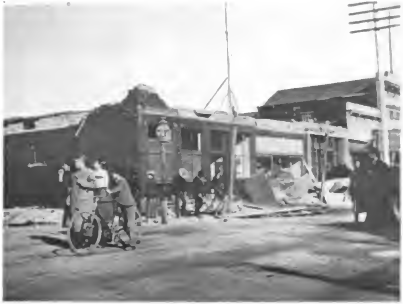
HOLLISTER TO PRIEST VALLEY.

Hollister (G. A. Waring).—At Hollister (plate 114c, D) the chief damage was to the Grangers' Union, the Rochdale store, the Catholic school, and the fire-house. The two stores were poorly built, however, with large rooms unsupported by partitions or columns, while their shelves were heavily laden with goods. The school was on tall underpinning, very slightly braced, which allowed the building to lurch northward and settle to the ground. Unsupported parts of the fire-house walls (2 bricks thick) fell outward, but the portion braced by posts and tie-rods was unhurt. Sixty-five out of 123 chimneys fell, or 53 per cent. Several locked doors were thrown open, in one case the bolt being broken. One old settler remembers when the business part of Hollister was a slough. An artesian belt also passes thru the town, which may have affected the intensity along its path.

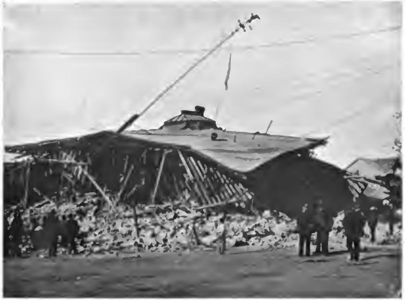
(A. J. Champreux.)—Practically all chimneys fell, the prevailing direction being east-west. One frame house, "School of the Sacred Heart," 2-story, was completely wrecked. The foundation gave way in the front part of the house, allowing the floor joists to drop.



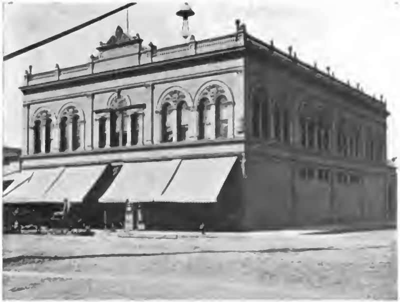
A. Gilroy.



B. Gilroy.



C. Hollister. Demolition of brick building shown in D. Blakesley, Photo.



D. Hollister. Same building as shown in C, before earthquake. Blakesley, Photo.

This house was on the outskirts of town and on sandy soil. No other frame house was damaged. Two brick buildings, of poor construction, collapsed. The outer walls gave way, allowing the interior to drop.

(James Davis.)—Two shocks were felt, of which the second was the stronger. There was an interval of 3 or 4 seconds of less motion between these maxima. A rumble preceded the shock by a second or so. In my house a piano and other heavy objects were moved on a polished floor so that the north ends moved 2 or 3 feet out into the room farther than the south ends. I was standing at the time of the heaviest shock, and was thrown from side to side in a north and south direction. People here all agree as to the north and south direction of the movement. Most chimneys fell north, but some fell east and west. Pictures on east and west walls, hanging by single wires 4 to 6 feet long, swung from 3 to 8 feet along the walls, leaving distinct scratches. Pictures similarly hung on north and south walls simply pounded back and forth, leaving punctures in the plastering. Water-tanks seem to have fallen to the north always. Three brick buildings, each 2-story, 1 old and 2 new, went down flat, and 2 others were badly damaged. Wooden buildings in general were not damaged except thru the fall of chimneys. The Catholic convent, however, was injured.

There were no changes in the ground at Hollister save some slight cracks in the vicinity; but a small peak near Santa Ana showed a landslide down its steep face, plainly visible at a distance of 6 miles. A huge rock, rolling down a hill in Santa Ana Valley, crashed thru a house and killed a man.

(J. N. Thompson.)—All brick buildings were destroyed or badly damaged. There were 2 shocks, lasting in all about 50 seconds. The first appeared to be north and south, and the last part of the second shock appeared to be a twisting motion or a change to an east and west motion. My chimneys fell first, and nearly to the south; then at the last motion my wind-mill and tank fell to the west. The most damage was done at the close of the last vibration. A sideboard against a north wall was moved several inches to the south, and a clock on the same wall was thrown to the south. A bed against the west wall moved several inches to the east.

From Hollister to San Benito (G. A. Waring). — The effect of the shock upon alluvial soil is very noticeable. In the hills toward the Stayton Mines the shock was so feeble that it was not noticed by some people. Thru Brown's, Los Muretos, and Quien Sabe Valleys it was generally only sufficient to throw the cream from pans of milk. The often repeated story of the man who was killed in Quien Sabe Valley, by a rolling boulder crushing his house, is not to be accepted as a measure of the intensity. Several loose rocks were shaken down in the neighborhood of Santa Ana peak, and springs increased their flow; nevertheless the shock was very light.

At Palmtag's winery, in the hills southwest of Tres Pinos, the shock seems to have been more severe than elsewhere in the vicinity of that village. Furniture was moved, water was thrown from troughs, and an adobe building was badly cracked. One low brick winery was unharmed. A distinct rumble preceded the shock; 2 distinct periods were felt and the shock seemed very long. There is a small lake on the Palmtag place, and the ground seems rather marshy. Possibly this had some influence on the intensity, tho there is reason to believe that the projection of the fault passes thru the hills in the immediate vicinity.

At Tres Pinos, out of 18 chimneys only one fell and it was unstable. Shelf goods were almost unaffected. There is hard rock (sandstone or shale) in place, however, at a depth of 2 to 4 feet, at Tres Pinos.

Paicenes, tho south of Tres Pinos, was more violently shaken, for it stands on gravel. Milk and water were spilt somewhat, and a few tall bottles were thrown from the shelves. Water is said to have spouted up in the flat land along the river, 0.25 mile from the stream.

Toward the Cienaga lime-kilns the intensity lessened considerably. One man in the foot-hills 4 miles southwest of Paicenes, reports seeing a wave coming westward thru a grainfield, and some oaks waving considerably; but he did not hear nor feel any shock. Four miles southwest of Paicenes, a hanging lamp swung strongly east and west, and milk was spilt from the pans. At the kilns, in a granitic region, tho a distinct noise is said to have preceded the shake, only one slight shock was felt, and that was not sufficient to spill water from a full bucket standing on a table. Along the river between Paicenes and Mulberry, a distinct vertical motion is reported, causing weighted windows to be thrown up and down, and stove-lids to dance about. Liquids were strongly affected, as were trees and hanging lamps, and a few articles were thrown from shelves.

On the afternoon of June 13, a lady near Mulberry, 5 miles south of Paicenes, was talking over the telephone with a friend in Hollister. The latter suddenly gave a startled cry as a slight earthquake shock occurred. It was felt at Mulberry several seconds later. From Mulberry to San Benito the shock uniformly lessened until, at the latter place, altho distinctly felt, even liquids were not disturbed by it.

Thru Bear Valley the only noticeable effects of the shock were the swinging of lamps and the disturbance of water surfaces. Little or no sound was heard in Bear Valley, but several people noticed 3 distinct periods of vibration. It began easily, rapidly increased, and then, after a pause, there came a harder shake. At one house a lamp hanging by a chain 3 feet long is said to have swung north and south nearly to the ceiling. Articles on shelves were not moved, nor loose window lights shaken out. At the summit at the south end of Bear Valley, about a bucketful of water was thrown from a barrel only two-thirds full, and cream was thrown north and south from pans of milk. Here also the hanging lamp swung strongly north and south. A man outdoors became dizzy and nauseated, but did not at the time realize the cause.

Thru the south end of the valley, hanging lamps are said to have swung east and west, and water is said to have spilt mostly east and west. Several people became dizzy, but the motion seems to have been too slow to be distinctly appreciable.

At the Pinnacles no loose rocks were displaced, so the movement must have been slight.

Traveling southeastward from San Benito up the valley toward Hernandez, the motion consisted of longer, slower vibrations, and was of remarkably long duration. In general, the effect was only to set rocking-chairs in motion, cause doors to swing, and trees to sway. Just south of the divide between San Benito and Hernandez Valleys, the intensity rose noticeably, the shock throwing a lamp and clock from a shelf.

At Hernandez, pans of milk and troughs of water were almost emptied, and many minor shocks have been felt since. No noise was heard before the quake, but a report as of a blast immediately preceded the second (hardest) period of vibration. This is in an upland valley at 2,500 feet elevation, but the ground seems to be full of water.

In the mountainous serpentine area between Hernandez and New Idria, the shock was evidently slight, as nothing was noticed to have been disturbed at Smith's camp. At New Idria a few bottles and light articles were thrown from shelves, clocks were stopt, and a few bricks loosened from a building erected with mud mortar; but chimneys were not injured. One brick furnace was cracked, but it was not properly braced. Only 3 minor shocks have been noticed at New Idria. The intensity was about the same as at Hernandez.

In Vallecitos Valley, at an elevation of 2,000 feet, Tertiary rocks are overlain by 50 feet or more of alluvium. In this valley, pans of milk were slightly spilt, but nothing was thrown from shelves.

From San Benito southward thru the Bitterwater Valley, the intensity lessened, and only liquids were affected. The motion was too slight to be appreciable to some people.

Priest Valley (D. S. Jordan). — On May 18 I went to Priest Valley, in the southeast corner of Monterey County, 37 miles east of King City. I had heard that rumblings were frequently heard in the valley, and that people were moving out on account of them. There was little trace of the earthquake at King City. At Lonoak, 16 miles east, chimneys were thrown down and a mild earthquake was felt. At Priest Valley, which is near the line of the old fault and at the very foot of the main range of the Gavilan, the earthquake shock was very severe, apparently coming from the north. Chimneys were thrown down, dishes were broken, and the contents of the store thrown over the floor. Rumblings were alleged to have been heard by a man named George Brew. He had been hunting in the mountains, and said he had heard noises like cannonading in the ground at night. This was before the great shock.

There were slight landslides and cracks along the edge of the creek banks. There is, however, no trace of the great crack in the valley. No one had seen it cross the stage road; and the oil pipe line from Alcalde, in Fresno County, goes thru to the Salinas Valley without any break. The people said to be moving out of the valley were two frightened women up in a mountain gorge, whose husbands had gone to look after friends in San Jose. It is evident that the main crack did not reach as far as Priest Valley, and the shock at that point was not very different from that at San Jose, except that the blow was more direct, with less twisting motion.

MONTEREY BAY AND EASTWARD.

Pacific Grove, Monterey, and Del Monte (A. S. Eakle). — At Pacific Grove very slight damage resulted from the shock, altho according to residents the vibrations were very severe, in a northeast to southwest direction. Only one or two houses had chimneys cracked, tho there are several massive chimneys, some with heavy ornamental tops.

The town is situated on massive porphyritic granite, and the overlying soil is not deep. Its situation was evidently the reason for the slight damage done. The Pacific Grove light-house is situated about a mile southwest and this showed more severe effects. The lamp is enclosed in a ribbed metal frame which rests on a brick tower and dome. The vibration of the ribs caused them to strike the metal chimney in the center of the top and dent it on the easterly side. The motion of this upper portion caused the brick dome supporting it to crack immediately at the base of the curved dome. There was no displacement of bricks, the crack being a fine one, visible both within and without the tower, and completely encircling it. The light-house is built on a sand-dune and there is an estimated thickness of 80 feet of sand upon the underlying rocks. This sand foundation probably accounts for the apparently greater intensity of the shock here than in the town. Some of the objects in the rooms of the house were also slightly misplaced.

Judging the intensity of the earthquake by the damage it did in Pacific Grove, it would probably be classed as VI in the Rossi-Forel scale, as it was severe enough to awaken practically every one, tho no windows were broken, so far as could be ascertained.

Monterey experienced practically the same intensity. I could learn of no damage done to the houses, the only damage reported being of some glassware in a few stores. In some houses furniture was moved slightly, and top-heavy pieces were overturned. This town, like Pacific Grove, is on a good rock foundation; but in places the sand is deep.

Del Monte suffered the most, as practically every chimney of the hotel was cracked or thrown. There were over 50 chimneys in the hotel, and half of them were thrown down, one crashing thru the roof on the west side of the hotel and causing two fatalities. The chimneys were tall and top-heavy, having ornamental tops; and while the damage to the interior of the hotel was very slight, showing that the earthquake was not of a violent type, the vibrations were sufficient to throw these top-heavy chimneys. The hotel is on alluvium, and the grounds surrounding it are in part "made" land. The grounds are surrounded by marshy land, ponds, and sand-dunes, and there is evidently a considerable depth of an incoherent, water-saturated formation supporting the hotel; this probably explains why Del Monte suffered so much more than Monterey. The houses adjoining the grounds were not damaged, with the exception of the school-house, which had its chimney cracked at the base.

On the road eastward to Salinas from Del Monte, no visible signs of the earthquake were encountered until the Salinas River was reached. The Salinas bridge was moved southerly several feet, according to report, and the framework was broken so as to render the bridge unsafe. The bridge farther down the stream, on a wagon road from Castroville railroad station to Monterey, was also damaged by the shock. This bridge crosses the river in a northeast to southwest direction, and is supported by four tiers of piles, boxed around with plank. The two end piers were not misplaced, but the two intermediate series were bent or broken at their bases and shoved over to the northeast, causing a sinking in the center of the bridge of about 2 feet. The damage to the bridge was due to the violence of the shock, and not to a sinking of the ground, as the amount of drop in the center was equivalent to the slanting position of the two intermediate supports.

Castroville to Soquel (G. A. Waring). — Castroville, being on solid ground, was not seriously affected. Three chimneys out of about 30 fell. Objects were thrown mostly westward. The quake was described as beginning like a subterranean blast. Two periods were not noticed; it was felt as one continual vibration, starting very gently.

The wharf at Moss Landing buckled up and partly collapsed, while the warehouses were wracked or fell westward. (Plate 116D.) At the hotel and stores on the mainland, brick chimneys fell, but plastering was not seriously cracked.

At Watsonville about 90 per cent of the chimneys were broken off at the roof-line, the greater portion being near to the river. Several were cracked and twisted but not thrown down. Parts of a few brick walls near the river fell, and considerable settling of the ground took place in Chinatown on the southern side of the river. (Plate 116A.)

On the higher ground between Watsonville and Aptos, the shock was little felt. There was no movement along Aptos Creek, both wagon and railway bridges being unaffected.

In one old house about half the plaster was thrown from every northern and southern wall on the first floor, but not from the others, nor from the upper rooms. A bureau was moved eastward 3 feet from the wall, but no other furniture was moved.

Nearly all the chimneys at Capitola fell, and considerable plaster was shaken from the north walls of the first floor of the hotel. The vibration is said to have been almost entirely east and west, as shown by the sash locks having been broken only upon the east and west windows. An iron safe free to move northward was unmoved, but the plaster on the opposite side of the wall back of it (west) was broken. A case of pigeon-holes resting on top of the safe slid to the east edge, when it could as easily have moved north. Much earth fell from bluffs near the town, but there was no appreciable effect on the surf. At the country bridge across Soquel Creek, the ground at the east abutment shoved inward, cracking the concrete and buckling a water-pipe.

In the low ground at Soquel, nearly all the chimneys fell, but most of those on high ground stood. Much plaster fell and goods were thrown from the shelves in the business section, which is close to the creek. The east abutment of the concrete wagon bridge over Soquel Creek cracked vertically, showing that the soil movement extended this far up the creek. Thru Delmar, Seabright, and Twin Lakes nearly all the chimneys were either down or twisted part way around and left standing, an unusual number being thus twisted. The shock is said to have come suddenly, diminished, and then, at a second jolt, chimneys fell. Trees moved sideways as well as swayed, and all animals were much frightened. One small stream has diminished in flow.

(D. Stirling.)—In the Pajaro Valley, on the McGowan ranch, at a bend of the river, an acre or more of orchard has sunk about 2 feet. At Moss Landing, where the river runs parallel with the shore line, the strip of land is seamed for miles. A crack, or rather a sink, about 20 feet wide and 4 or 5 feet deep ran under the buildings and rent them asunder. The office building between this crack and the river has been moved bodily — land and all — about 12 feet toward the river. Some of the cracks run into the ocean. At Neponset and Salinas the piling under the county bridges was moved in some of the bents at least 10 feet toward the river. A section man who stood in the midst of the cracks at the end of the Neponset bridge was drenched with spurting water.

SALINAS TO SAN LUIS OBISPO AND WESTWARD.

Effect of the Shock on Alluvium (G. A. Waring). — Altho the Salinas river bed sank nearly 6 feet at King City, and the wide sandy bottom at Three Mile Flat was much cracked, the southernmost extension of continuous cracks along the bank was found to be about 2.5 miles south of Gonzales bridge. From here to the mouth of the river the cracks are parallel with the river banks.

The movement at Gonzales bridge was mostly on the west bank of the stream. A wire fence trending north and south was torn 6 inches apart here, and wooden piles at the southwest end of the bridge, said to be driven down 75 feet, have been torn loose and moved from plumb, their original upright position. At the northeast end of the bridge the piles are undisturbed, but the surface soil and a wire fence have moved relatively 18 inches northward. (See fig. 59.)

North of Gonzales bridge the fissures are mostly on the west side of the stream channel, and reach a maximum width of 18 inches. No evidence of shearing could be found. In the creek bottoms west of Chualar, sand craterlets begin to appear and become numerous along the stream northward.

Near Agenda, in the lowlands, is a cracked area nearly a mile from the river, probably along an old water course; while sand craterlets are scattered thru the orchards. At Spreckels the movement caused much damage to flumes, sewers, and water-mains; and from here to Blanco the deep soil of the adjacent fields is much cracked and in places sunken and dotted with sand craterlets.

The county bridge south of Salinas was rendered unsafe by the movement of the piers at the southern end. (Plate 123A.) On the west bank near the bridge a series of peculiar cracks have torn up the road and adjacent field, along what is probably the path of an old water course. These are shown in plates 136, 137.

Between Blanco and Neponset the cracking and settling of the low land flooded the adjacent fields and gave rise to stories about the Salinas River having risen several feet. The "boiling up" of the water thru sand craterlets was also soon distorted into a story about the water of the Salinas River being boiling hot. Both the railway and county bridges at Neponset were moved, the northern concrete piers of the former 2 inches east and the central wooden pier of the latter apparently 4 feet south.

From Morocoho to Moss Landing fissures rarely show in marshy land, but the narrow-gage railway track has been shifted a few inches in several places. At Moss Landing many small cracks occur in the mud on the west side of the river, and the condition of the wharf indicates an eastward movement of the sand-spit. (See plates 134B, 135A, B.) It is reported that at places along the pier where the water was formerly 6 feet deep, it now has a depth of 18 or 20 feet. North of Moss Landing the ground settled nearly 2 feet in places, as shown by marks on railway piles at several slough crossings and by the sagging of the track below grade line in several other places. The stretch of narrow-gage track parallel to the coast has been disturbed for nearly its whole length; in some places it is wavy, in others the entire roadbed has shifted. At one point about 5 miles south of

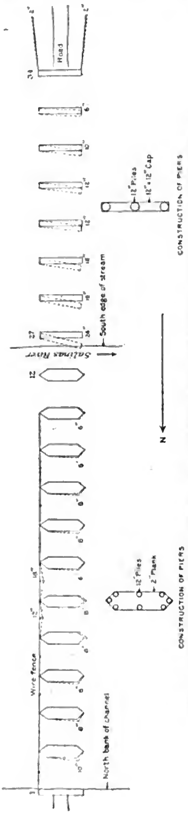


FIG. 53.—Displacement of piers of highway bridge across Salinas River, 3 miles west of Gonzales. The bridge is 1 mile long.

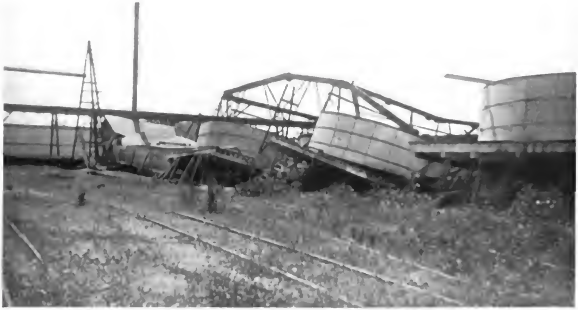
Watsonville, where the railroad track is only about 200 yards from the beach, a stretch 100 yards long running northwesterly had shifted a maximum of 12 feet to the northeast. Fences, telephone poles, and track all moved together. The sand-dunes facing the beach directly opposite the place where this movement occurred look as if they had been struck by a single large wave.

Cracks appear again along the Pajaro River and the railway track has sunk in several places. The side rods of the narrow-gage bridge 1 mile south of Watsonville are buckled as by a compressive force, and the roadbed at both approaches has settled at least 2 inches.

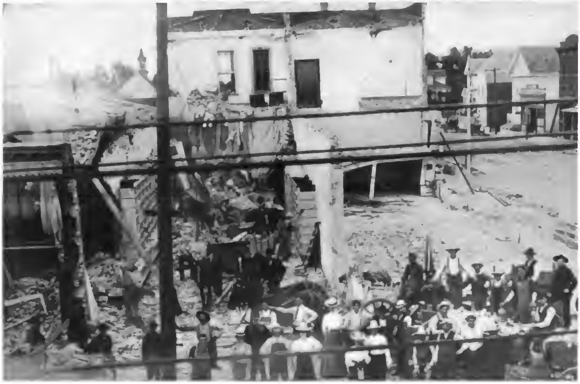
Continuing up the Pajaro River, evidence of settling is found at the broad-gage railway bridge at Watsonville, the southeast end of which sank more than a foot. The track was also twisted into an S-shape. The concrete foundation under the engine and stack at the power-house at the northwest end of the bridge settled, but the concrete work was little hurt. In Chinatown, on the south side of the river, the settling of the ground was marked.

Between Pajaro and Vega the ground cracked along the 2 to 6 foot bluff, marking the old river bank on the south side of the present channel, and the side toward the river has settled several feet. This is well shown in plate 141B. This displacement has caused numerous sand craterlets and pits (plate 143B); the largest pit noted being oval in shape, 6 by 20 feet in diameter, and 4 feet deep. Northeast of Vega the movement seems to have died out, the last evidence found being mud caps on some old piles in the channel of the stream, showing a settlement of the ground amounting to 8 inches. Between Vega and Chittenden no evidence of movement of the river-bed could be found. Near Chittenden the banks are caved in. Along the San Lorenzo River, at Santa Cruz, this settling action also took place for a mile or more upstream from its mouth.

It may be said, regarding the soil movement along these streams, that along the Salinas River from Gonzales to near Blanco, everything shows a movement down the river. From Blanco to Neponset the movement seems to have been a settling of the alluvial materials, while from Neponset to the mouth of the Pajaro River the ground (in several places, at least) moved eastward or inland. Accepting as correct the reported lengths of piling at bridges, and depths at which the sand thrown up is said to have been found, the plane of movement must have been about 90 feet below the surface at Neponset, diminishing to possibly 8 or



A. Alvarado. Wreck of molasses tanks, Alameda Sugar Company. E. W. B.



B. Salinas. Wreck of corner store. G. R. B.

10 feet at Gonzales bridge and ending about 2.5 miles south of it. Along the Pajaro and San Lorenzo Rivers the movement was a settling of the alluvial bottom-lands.

(A. S. Eakle.) — The effect of the earthquake upon the alluvium was well shown along the banks of the stream from the Salinas to the Gonzales bridges. Along the east side of the river for a short distance south of the Salinas bridge, 4 miles south of the town, the land is cracked at the edge of the bank, the cracks paralleling the course of the river; but comparatively little cracking was observed on this side of the river. Along the bank and down in the river-bottom itself, on the western side of the stream, fissures were very prominent. The county road southward from the Salinas bridge runs along the embankment about 10 to 20 feet above the stream bed. The road is an oiled one, and the oil had formed a hardpan upon the underlying sand. In the vicinity of the bridge the road has been shattered by the quake for a distance of 200 yards. The breaks are in the nature of a caving in of the road on the north side of the crack, as if hollow spaces existed beneath, leaving a vertical escarpment on the south side. The main sinking is at the most southerly fissure. Here the road has sunk bodily to a depth of 10 feet, leaving a high vertical bank diagonally across the road, and this sunken area extends for some distance into the adjoining field on the west. There is no upheaval of the road in any place to compensate for the sinking.

South of the Spreckels factory, the low bottom-land between the banks of the river is considerably cracked, although there is no prominent vertical dropping of the land along the cracks. This low land lies west of the present course of the stream, and is intersected by sloughs and former water courses. All of the ground is of a deep sandy nature, consequently it was much disturbed and fissured by the quake, and the fissures became filled with water and sand, forming a quicksand, this wet sand frequently being spouted into the air. No one noticed gases coming up. The position of the cracks is now marked by patches of light, bluish-gray sand in the field, from the drying out of the quicksands. Houses on this low land were thrown out of plumb, and chimneys were destroyed. The cracks diminish in number as one goes southward, and practically end in the vicinity of the Gonzales bridge. The quake at Gonzales can hardly be placed at more than VII in the scale, as comparatively little damage was done to the town.

Effect upon structures, objects, etc. (G. A. Waring). — It is remarkable how closely the disturbance followed the river channel throughout the Salinas Valley; 2 or 3 miles away from the stream on both sides the intensity was very slight. Southward up the valley the shock gradually lessened, and rapidly died out in the foot-hills on either side.

In the hills between San Juan and Natividad the ground is not cracked, except for a few places on hillsides where there was some sloughing off. The shock was sufficient to throw nearly all the milk from the pans, but not strong enough to move furniture or shelf goods. At Natividad, in the foot-hills, the shock was of about the same intensity. At Santa Rita the shock was light; a little milk was spilt from pans, but several tall slender chimneys were unhurt.

Prunedale (H. H. McIntyre). — Nearly every chimney was thrown down. All the goods in the store were thrown to the floor. The house was badly wrecked. Water started flowing in many places where there had been none, or but little, before. There were 2 small landslides from springy places, the direction of the slip being from north to south.

Salinas (G. A. Waring). — At Salinas 42½ per cent (278 out of 655) of the chimneys fell. A brick store was demolished by the collapse of the roof (plates 115B, 116B), and parts of a dozen or more brick walls fell. (Plate 116C.) Shelf goods were shaken down, and a few heavy articles, such as slot machines, were overturned. Heavy furniture, such as pianos and billiard tables, was not moved. But little plate glass was broken. In some buildings plastering was badly cracked and shaken down, but in solid, well-built residences it was little hurt. The court-house and high-school buildings, within a block of each other, furnish striking examples of the need of considering construction when trying to gage the intensity of the shock by its effect on buildings. In the former building the principal damage consists of a few cracks in the plastering and foundations, while in the high-school building a part of the front wall fell out and the roof spread badly, cracking the corners of the house.

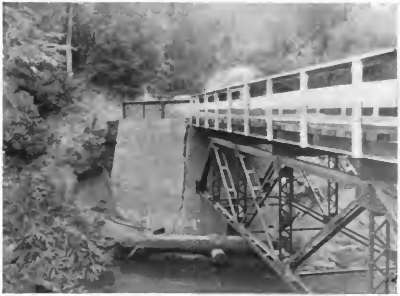
(A. S. Eakle.)—The town of Salinas suffered greater destruction than any other place in the county. Nearly every house and building were damaged to some extent. Plaster fell, windows broke, chimneys fell or were cracked, and brick buildings had their upper portions thrown off and, in some cases, almost completely demolished. The town is on the flat valley land, about 3 miles east of the river, and came within range of the more violent vibrations, in addition to being on alluvium.

Spreckels and vicinity (G. A. Waring). — The village of Spreckels, on the river-bottom, was badly shaken. Nearly every one of the approximately 50 chimneys in the settlement fell, as did also a large part of the plaster in the 3-story hotel. On the first floor of the hotel building nearly all the walls were stript, but the plaster fell mostly from the south wall. On the second floor the walls of the north end and west side suffered most, while on the third floor the north end (walls and ceiling) was shaken the hardest. In the 6-story, steel frame, brick sugar mill (plate 117A, B) the bricks along the I-beams of the north end were thrown out, as were also those of the upper central part of the west wall, and part of the top cornices of the north and south ends. Oil in a large tank was thrown toward the southeast. The front (north end) of the 2-story brick office building exhibits a remarkably symmetrical set of cracks.

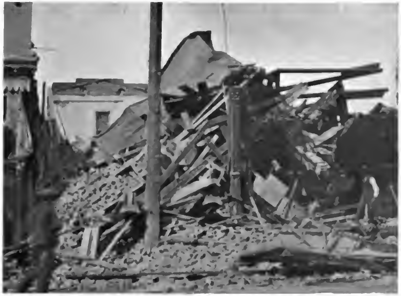
(A. C. Lawson.)—The flood plain of the Salinas River was caused to lurch toward the stream from both sides, but the effects are most marked on the south side. The result in most places has been the breaking up of the alluvium into monoclinal strips with a vertical scarp on one side, facing the river, and a gentle slope on the other. These have the effect of landslide scarps and terraces, but occur on flat land. In some instances it would appear that the ground had collapsed into the cavity formed by the lurching. There are minor cracks and buckles in the sand and mud flats of the river-bottom. Here numerous craterlets were formed by the sudden ejection of water from the underlying sands, due to the compressive action of the shock. This acute deformation of the ground accentuated the destructive tendency due to the earthquake shock.

At the bridge, a large trussed structure in 2 spans having a bearing of N. 27° E., the south pier, consisting of 26 piles incased in planking, was thrust to the south between 6 and 7 feet, so that the entire pier was inclined as shown in plate 123A. The piles were not broken at the ground level. The north and middle piers were apparently not affected. An oil pipe which crost the bridge was buckled and twisted at the south end of the bridge, and when this was repaired the pipe was found to have been shortened 7 feet. The pipe line extends from the San Joaquin Valley to the Bay of Monterey. A few hundred yards to the south of the bridge is a pumping station, and at this point some of the connections of the pipes were broken and displaced. The direction of the shortening of the bridge span and the pipe is roughly normal to the direction of the San Andreas Rift, on the other side of the Gavilan Range. Mr. S. A. Guiberson, superintendent of the line, reports that the pipe was broken in about twenty places in the vicinity of the river, and that at some of these breaks the pipe was pulled apart.

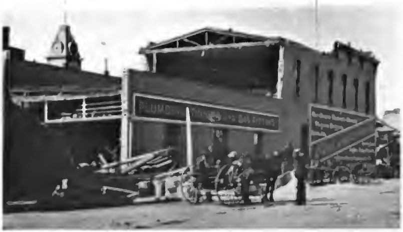
A few hundred yards east of the bridge, on the south side of the Salinas River, is the Spreckels sugar-mill, a steel structure incased in brick, about 500 feet long and about 150 feet wide, having a northeasterly and southwesterly orientation. This building is five stories high, but the five stories occur only at the two ends of the building. In



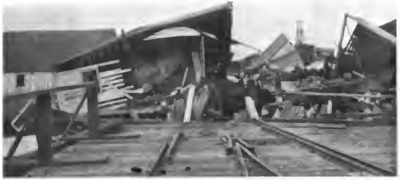
A. Near Watsonville. Concrete pier of bridge shattered. Per J. C. B.



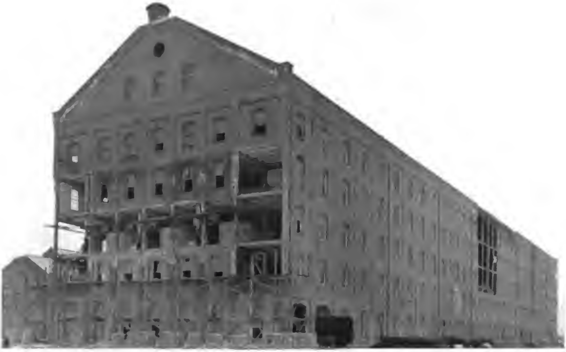
B. Salinas. Wreck of store. G. R. B.



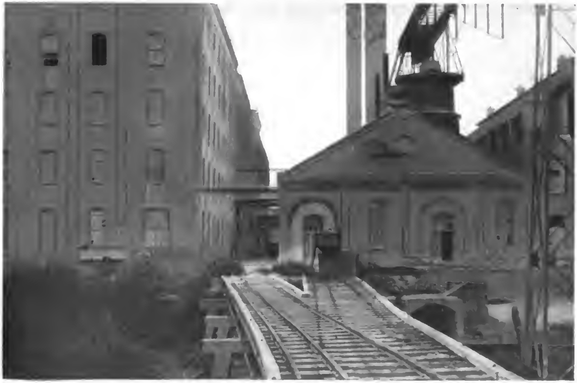
C. Salinas. Walls of building thrown out. G. R. B.



D. Moss Landing. Wreck of wooden warehouse. G. R. B.



A. Spreckels sugar mill, near Salinas. Entire building buckled. Looking southeast. R. L. H.



B. Spreckels sugar mill. Looking northwest. A. C. L.

the middle 100 feet of its length there is only one floor above the ground-level, and above this the structure is open to the roof, without cross-ties or floor-beams. This building yielded to the shock in a most remarkable and instructive manner. The whole structure was shortened along the line of its longer axis, this shortening being effected by the buckling of the walls at the middle or weak portion of the building. Both walls bulged toward the west, the east wall in and the west wall out, as shown in plate 117A, B. Within the building considerable damage was done to the heavy machinery, tanks, etc. The ground to the south had been much heaved and otherwise deformed, causing the wrecking of trestles, pumping-house, and other structures. The rails of a track at the rear of the building were pulled apart, due probably to the slumping of the ground toward an old slough of the river.

In the bottom of this slough water gushed forth at numerous places at the time of the earthquake. It is said by those who witnessed the phenomenon that the water spurted repeatedly as high as 20 feet, and that the outflow of water lasted for 10 minutes after the shock. The places where the water spurted forth are marked by areas of fine, light, bluish-gray sand, which is said to be known only at a depth of 80 feet in the various well borings of the vicinity. In these areas of fine bluish sand are often funnel-shaped depressions or craterlets from which the water issued.

(S. A. Guiberson, Jr.)—As superintendent of the pipe line, I am in a position to say that we have no breaks whatever in any place between Coalinga and the Salinas River, and there were no fissures of any kind along the line between these points. This I know positively, as I have line riders who were instructed to look closely for any disturbance of this nature. The line of fissures seems to have ended north of Priest Valley. The conditions prevailing along the Salinas River, and some of the peculiar circumstances attending the breaking of our line in about twenty places, are of interest. I was on the ground the following day, and only regret that I did not have time to have some of the peculiar features photographed. In places our line had been broken and the ends were 3 feet apart; at the same time the ends of the pipe would be hammered up, showing that there had been an opening and closing movement at that point, while at other points the line would overlap as much as 4 feet. One of our stations is in this zone of disturbance, and the engineers, being on duty, had an excellent opportunity to see what most of us who were in bed merely felt. They state that these fissures were opening and closing, and that the water and sand would go 20 feet in the air as they closed.

Southward from Salinas (G. A. Waring).—At points along the railroad liquids were generally spilt, furniture was moved, and chimneys cracked. At Chualar, 3 out of 29 chimneys fell, but 2 were on an old house and were probably weak. At Gonzales the intensity seems to have been about the same as at Chualar. Out of 150 chimneys 11 fell, while many were cracked. East of Gonzales, near the foot-hills, houses were barely shaken; while to the west, near the river, water-tanks were thrown down. At Soledad 3 out of 8 chimneys fell, but the number is probably too small to be taken as a criterion of intensity. Some plastering on the first floor of the hotel was slightly cracked, a few glasses were thrown from the bar, and some of the bottles were turned around. The frame of the railroad tank was so badly twisted that it had to be taken down. A chandelier swung northeast-southwest with a double amplitude of 18 inches.

At King City, close to the river and on low ground, the intensity was considerably higher than at Soledad. Heavy objects, such as a printing-press, slot machines, and ice-chests, were shifted a little, and a few things were thrown from the shelves. One low chimney on a low fire-wall fell, but the wall was without a crack. No other chimneys were injured. The river-bed sank nearly 6 feet in the vicinity of King City. At San Lucas the intensity was considerably lower; milk and water were spilt and shelf goods disturbed, but no chimneys fell.

On the western side of the valley from Salinas to San Lucas the same kind of evidence was found as at corresponding points on the eastern side. At Fort Romie most of the clocks stopt, a few articles were thrown from the store shelves, and water in a north and south canal was thrown over the sides. No sound was heard during the shake, but it is reported to have come afterward.

About 4 miles south of Fort Romie, water was thrown 30 feet northward from a full tank, the top of which is 14 feet above the ground, and half the milk was thrown from half-filled pans. West of San Lucas, waves were reported to have been seen moving southward over the hills and a sound to have been heard. The shock began gently, was followed by a harder shake, and died away slowly. Thru San Ardo, Bradley, and San Miguel, the shock lessened uniformly. At San Ardo a water-tank frame was somewhat wrenched, and the river-bed is thought to have sunk about 2.5 feet, tho evidence of this was not obtained. Oil was spilt from a large tank, and quicksand was thrown up in a well, which seemed to lessen the flow considerably. The railway station at Bradley, standing on made ground, settled 2 inches at one end.

At Paso Robles a number of clocks were stopt, most of which were facing east or west. Window weights rattled and lamps swung about, but plastering and shelf goods were not affected. The duration of the shock was estimated at 40 seconds, but was very gentle.

In the southeastern end of the Salinas River drainage area, at Shandon, Cholame, and Parkfield, the shock was notable as being "the longest, easiest one felt in many years"; liquid surfaces were somewhat disturbed, a few clocks were stopt, and hanging objects were set in motion. In the hills 2 miles northwest of Shandon the intensity was somewhat greater, as it was also to the southeast in the Red Hills. At Shandon, a saddle hanging by a wire from the rafters swung north and south, and water was thrown from a full horse-trough. The shock was also reported at Estrella and Linne.

South and West of Salinas Valley (G. A. Waring). — Following southward over the divide thru Templeton, Santa Margarita, Dove, and Guesta the shock lessened until it was hardly more than distinctly felt. At Templeton skimmed milk was spilt at one place, but unskimmed milk was not. At Dove the swaying of the telegraph wires was about the only evidence noticed. At one place a mile east of San Luis Obispo a great roar is reported to have been heard.

In the coastal range of hills thru Carmel P.O., Jamesburgh, and Jolon, only milk and water were disturbed, but from the latter place to Los Osos Valley, west of San Luis Obispo, the shock varied considerably. At Lockwood the shock was a little stronger than at Jolon, clocks being stopt generally and milk and water spilt, but no shelf goods were moved. Thru Hames and Pleyto it hardly more than wakened sleepers, and people moving around did not feel it; while at Adelaide clocks were stopt, shelf goods moved, and liquids spilt. Several minor shocks have also been felt at Adelaide. In Los Osos Valley, however, the shock was barely felt; sound sleepers were not awakened. A few light things, such as table covers, swayed slightly, but no sound was heard, and pans of milk were undisturbed.

At San Luis Obispo the shock was hard enough to waken all ordinary sleepers. Some people thought it a wind-storm. The vibration is estimated by some to have lasted 20 seconds. Mr. John R. Williams states that the shock made doors and windows rattle, moved his bed, and stopt some clocks. There was but one principal disturbance, which gradually increased in intensity and then died away, lasting about 50 seconds. The apparent direction of movement was northeast and southwest. The night operator at the telephone office was talking with Salinas at the time the shock occurred. She heard a scream at the Salinas end, followed by a roaring sound. Fully half a minute later the shock was felt by her at San Luis Obispo.

Along the coast northward from Port Harford thru Morro, Cayucas, and Cambria, to San Simeon, the intensity gradually rose. At Morro some people in bed and awake felt it; many others did not; while at San Simeon liquids were somewhat disturbed and the shock of the afternoon (of April 18) was also noticed, which was not the case farther south. At Piedras Blancas Light-house a clock stopt and the shock was distinctly felt.

Between San Simeon and Posts the country is almost uninhabited, and not easily accessible, so it was not visited. At Posts a clock was stopt. The shock was very appreciable, and several minor ones have been felt since. At Idlewild several articles were thrown from shelves, windows rattled, and the redwoods swayed considerably. At Sur a clock was stopt and the shock was apparently a little stronger. At Carmel-by-the-Sea, on deep, sandy soil, several people ran out of doors, a cobble-stone chimney fell, and a few tall articles were tipt from shelves.

SAN LUIS OBISPO TO SAN BERNARDINO.

This portion of the state is on the southern fringe of the region within which the shock appealed to the senses. The shock was not exceptional in intensity and the people paid little attention to it; therefore records of observations as to the effects produced are few. Such reports as have come in, however, indicate that the shock was more or less distinctly felt thruout the country north of the Santa Barbara Channel and the Valley of Southern California, as far east as San Bernardino.

Arroyo Grande, San Luis Obispo County (G. P. Ide). — Pendulum clocks facing north and south were stopt, while those facing east and west were not. Very few objects were overthrown. A hanging object swung east and west in an elliptical orbit.

Other points south of the town of San Luis Obispo at which the shock was reported are:

Pismo: Hanging objects swung from east to west, and some clocks stopt.

Edna and Oceano: Clock stopt.

Port Harford: Slight shock.

Santa Maria, Santa Barbara County (F. R. Schank). — I was asleep in the second story of a brick building and was awakened by the first of 3 shocks. The shock awoke people generally and was observed by persons moving about, but did no damage. The motion was a slow, easy one. Wooden inside shutters at my windows swung thru a considerable arc, and an incandescent lamp suspended by about 5 feet of cord vibrated with an amplitude of about 6 or 7 inches in a plane approximately east-northeast. The length of the first and second shocks was 1 or 2 seconds, but the third shock lasted between 12 and 15 seconds.

Casmalia, Santa Barbara County (C. H. Stephens). — I was awakened by the jar, and the rocking was continued for about a minute, when all became quiet. It then started again lightly, getting stronger as it proceeded and gradually dying away in about 45 seconds. The third shock came quite strong, and 6 waves followed close on each other, each stronger than the preceding one. The clock was stopt, and some articles of furniture were overturned.

Surf. — A clock was stopt.

Lompoc, Santa Barbara County (C. K. Studley). — I was in bed, awakened by the first slight trembling. My bed stands east and west, with the head to the west. The first shock moved me up and down from head to foot. The second shock rolled me from side to side. The first shock gradually increased to a maximum, and then died out; the second seemed to be about the same intensity thruout, and stopt suddenly. The latter set the window weights on the south side of the house rattling quite rapidly. The hanging lamp suspended from the ceiling of the lower story by a chain, which would make it about equal to a pendulum that beats seconds, swung in an elliptical orbit, the longer diameter being 10 inches in a west-northwest direction and the shorter diameter 4 inches in a north-northeast direction. The motion in the ellipse was clockwise. The clock stopt.

Point Conception Light-house Station (Mr. Austin). — While cleaning up in the tower at 5^h 20^m A.M., the keeper felt the lens shake. No one else at the station felt the shock.

Santa Barbara (J. A. Dodge). — I was aroused from a half-sleeping condition by a singular rustling noise in the house. None of us recognized it as an earthquake at the time. My bed was not perceptibly shaken. Nothing was shaken out of place, no plastering was cracked, and no clocks were affected. The sound referred to was produced by something in the structure of the house creaking or vibrating. Other reports state that some hanging objects were caused to swing, and that one woman was made dizzy.

Carpenteria, Santa Barbara County. — The shock was sufficient to rattle dishes and slightly move beds, but few people were awakened by it.

Saticoy, Ventura County (E. O. Tucker). — Water in a trough which was 6 inches from being full, slopt over nearly a pailful at a time from the ends. The trough lies from northeast to southwest. A rattling noise was heard in the house, but no motion was felt.

Hueneme Light-house Station, Ventura County (C. F. Allen). — The earthquake was one abrupt shake which gradually died out, lasting 4 seconds in all. The weight to the clockwork which turns the light thumped back and forth in the weight-well from northwest to southeast, and the window weights did likewise.

In Ventura County a slight shock was reported at Newberry Park, Punta Gorda, and Ventura. At the latter place, hanging objects were observed to sway from east to west.

Calabassas (H. H. Wheeler). — A farmer stated that a number of cisterns for collecting rain-water for domestic uses were cracked by the earthquake shock so that they leaked.

Santa Monica, Los Angeles County (T. H. Moody). — A disturbance was noticed which seemed to be on the front porch, the noise continuing with considerable regularity, and appearing to change from place to place. Then there was other cracking around the house, and finally all was quiet. Nothing moved out of place.

Los Angeles (J. D. Hooker). — There was a light shock, then a heavier; then a smart shock which caused windows and doors to rattle. A window curtain swung in and out. A brass ring attached to a cord 15 inches long swung northwest and southeast. At the Weather Bureau station the barometers were observed to swing and rattle against the rings which confined them. The shock was also reported as a slight one at Azusa, Claremont, and Toluca, in Los Angeles County.

Anaheim, Orange County (J. F. Walker). — Very few people in Anaheim report having felt a shock at all. It was very slight. No clocks were stopt.

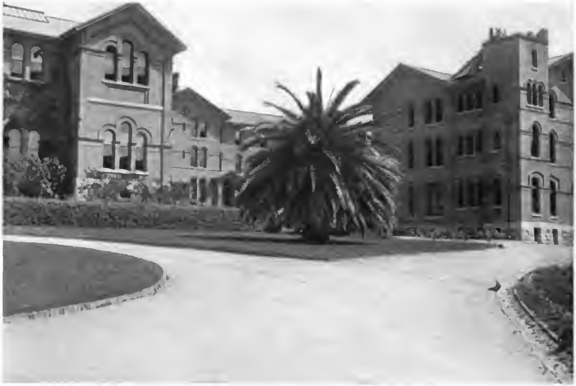
San Bernardino (Dr. A. K. Johnson). — The shock was sufficient to stop the town clock at 5^h 17^m, and several persons felt the vibrations, but no movable objects were displaced. At 4^h 30^m P.M., April 18, a slight oscillation was felt which caused the chandelier to sway. This movement continued for a few seconds, and seemed to be from northwest to southeast.

BAY OF SAN FRANCISCO TO THE SAN JOAQUIN VALLEY.

In Contra Costa and Alameda Counties the destructive effects of the earthquake were most manifest in the cities of Berkeley, Oakland, and Alameda, on the east side of the Bay of San Francisco.

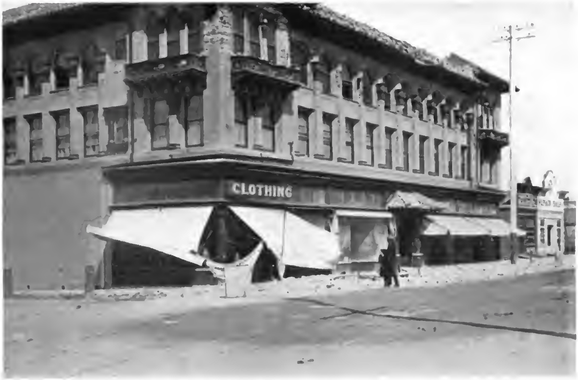
Berkeley (A. C. Lawson). — A large majority of the brick chimneys were broken or overthrown, and in addition to this several brick buildings had their upper walls thrown down or were otherwise damaged by cracks. The most notable cases of this kind of damage indicative of the intensity of the shock may be briefly mentioned.

At the State Institution for the Deaf, Dumb, and Blind the upper part of the northwest tower of the building, to the north of the central structure, was wrecked by a considerable

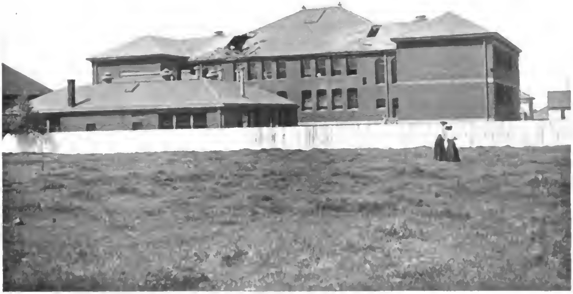


A. Berkeley. Institute for Deaf, Dumb, and Blind. South wing. A. C. L.

B. Berkeley. Institute for Deaf, Dumb, and Blind. North wing. A. C. L.



A. Berkeley. Barker Block. Shattuck Avenue and Dwight Way. A. C. L.



B. Berkeley. High-school. A. C. L.

part of the brickwork being thrown out on the northeast and northwest corners of the tower. (Plate 118B.) The upper part of a brick gable in the central building, facing northerly, was thrown southerly, or into the building. The upper part of the tower on the northwest corner of the building to the south of the central structure was demolished. (Plate 118A.) The main clock tower of the Institution, however, suffered no serious damage. The clock, a very unreliable one, stopt at about 5^h 13^m. At the High School the walls of the upper story, particularly those facing west, were badly cracked and partly thrown out, so that they had to be taken down. Two large brick chimneys on the east roof collapsed and did much damage to the rooms below. (Plate 119B.)

The Barker Block, at the northwest corner of Shattuck Avenue and Dwight Way, a building veneered in part with brick, had a great deal of the brick facing of the upper part of the building, and much of a strip of tiling above the east wall, thrown down. (Plate 119A.) The upper part of the rear wall of the brick building at the northeast corner of the same streets was thrown down. The north wall of the new Masonic Temple, which was in course of construction at the corner of Shattuck Avenue and Bancroft Way, was thrown to the north and caused the collapse of certain steel girders resting upon it.

The intensity of the earthquake within the city of Berkeley was by no means uniform. There were areas which seemed to a very considerable extent to be immune to the destruction so marked in the throw of chimneys, etc., in neighboring areas. The buildings on the University campus, for example, sustained no serious damage, and there was not a single chimney thrown, altho one or two were cracked. In a belt of the city extending northwesterly from the vicinity of the President's residence on the campus, the damage to chimneys was similarly light. This comparative immunity to destructive shock appears to be associated with the fact that the buildings on the campus, and in the belt to the northwest of it, are practically founded on rock, whereas the portion of the city where chimneys generally fell is on alluvium.

The direction of the fall of chimneys at Berkeley, as elsewhere, was controlled to a large extent by the orientation of the houses. Chimneys usually fell nearly at right angles to the longer side of their cross-section, which was as a rule parallel to one of the walls of the house. Notwithstanding this fact, however, there was a prevailing tendency in the fall of chimneys to the south and east, or in the southeast quadrant. Where chimneys fell to the east, they fell usually a little to the south of the line at right angles to the north and south wall; and where they fell south they fell similarly a little to the east of the normal to the east and west wall. Some square chimneys fell diagonally to the southeast. This was true of a rather massive 4-flue chimney on the writer's house, which fell at the latter end of the shock. In many cases chimneys were dislocated and twisted, without being thrown down. Of 38 chimneys, the rotation of which was noted by observers giving their entire attention to the matter for the time being, 31 were rotated counter-clockwise and 7 were rotated clockwise. In some parts of Berkeley the rocking of the houses was sufficiently violent to make it difficult, and in some cases almost impossible, to stand on the floor without support.

According to the observations of the writer, there were two maxima in the shock, with a lull in the interval, the second being the more violent. The movement appeared to be diagonal to the rectangle of his house, the longer side of which is approximately east and west. The throw of objects was much more to the west than to the east. This was well exemplified by the behavior of objects in the mineralogical museum on the third floor of South Hall. These are upright cases reposing on cabinets of drawers. The shelves, arranged in steps, are orientated north and south approximately, and face both east and west. On the shelves facing east very little was disturbed, while in those facing west many of the heavier specimens, weighing 20 pounds or more, were projected from the largest, or top shelf, thru the glass doors, and were found strewn on the floor. In no case, however, was the glass of the doors broken. The latter had been forced open at the same moment that the masses of rock had been hurled toward them, thus allowing the missiles to pass thru. Smaller specimens, weighing less than a pound, on the shelves immediately below the top one, were very little disturbed.

Oakland (A. C. Lawson). — The destructive effects of the earthquake were much more in evidence in Oakland than in Berkeley, and this is doubtless due in large measure to the much greater number of brick and masonry structures susceptible to this kind of damage. When particular instances are considered, however, it seems probable that the severity of the shock was in reality somewhat greater in Oakland than in Berkeley. Chimneys fell very generally thruout the city; the upper parts of brick walls, gables, and cornices were in many cases thrown down (plate 122B) and cracks in walls were numerous. The underpinning of some few old frame houses caused these structures to collapse. In addition to this damage, which indicates fairly well the prevailing intensity of the shock, there were several cases of more severe destruction which must be noted.

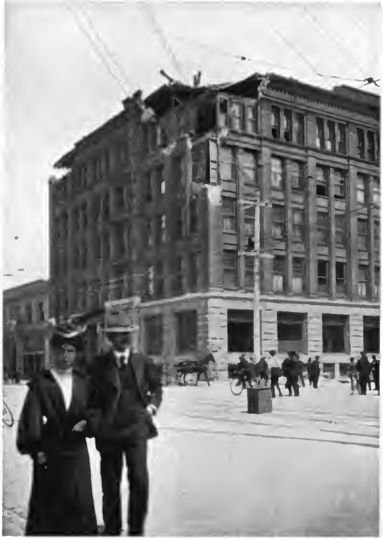
The Prescott school, in course of erection, at the corner of Ninth and Campbell Streets, was rather badly wrecked (plate 121B), as was also the building of the California Flax Works, on the corner of Union and Third Streets, the walls of which gave way, causing the roof to collapse. (Plate 121A.) The susceptibility of this building to destruction was probably due to lack of transverse bracing for the walls, except that supplied by the roof girders. The southeast tower of the First Baptist Church, on Telegraph Avenue, had its upper northeast corner thrown out, and was otherwise wrecked. (Plate 122A.) The east and south gables were both thrown out; but the lower towers at the northeast and southwest corners of the building were comparatively unaffected. The Central Bank building, at the corner of Fourteenth Street and Broadway, had the brickwork of its southwest corner thrown off from the 2 upper stories, and was similarly affected, tho to a less extent, on its northwest corner. (Plate 120A.) The large smokestack at the Key Route power generating plant, built on the tidal marsh land, had its upper third thrown off. (Plate 120B.)

Considerable damage was also done to the First Unitarian Church, at the corner of Castro and Fourteenth Streets, and to the Christian Science Church, at Franklin and Seventeenth Streets.

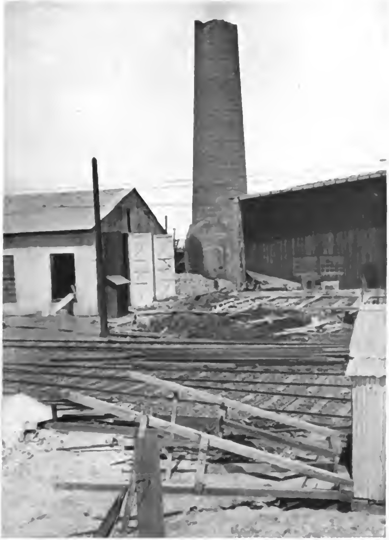
(E. C. Jones.)—There were very few breaks in cast-iron gas-mains. Two of these were caused by impact of heavy débris falling from buildings and poles. One was on Washington Street, where heavy blocks of sandstone fell from the third story and the roof, breaking the main 30 inches below the bituminous rock. Another was at the corner of Fourteenth Street and Broadway, where a transformer fell from a pole, striking the center of a short car rail and bending up both ends. A 3-inch cast-iron main a short distance from this was broken at right angles. On the Twelfth Street dam, a cast-iron pipe was broken and displaced over a foot; while the high pressure steel pipe paralleling it was practically undisturbed. Gas-holders were uninjured, tho much of the water was thrown out of the holder tanks. The only damage to buildings was the destruction of brick gables at Gas Station "B," First and Market Streets.

Oakland cemeteries (R. Newcomb). — In the Mountain View Cemetery, which is on a little draw between ridges, the chief damage done was the cracking of the receiving vault, and that was not injured very much.

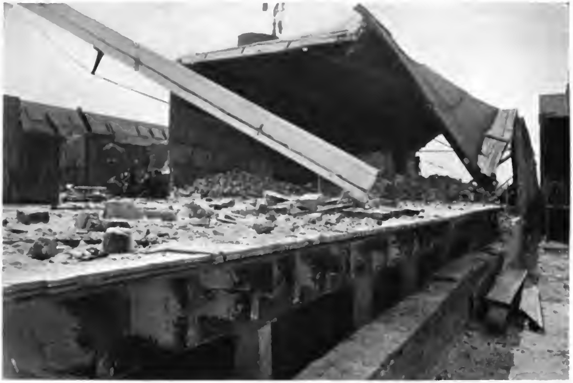
In St. Mary's Cemetery, on the small ridge to the west, however, many monuments were moved or twisted and several were overthrown. On entering the cemetery from the east, very little damage was observed, but on climbing the ridge more and more was noticed. On the north slope less damage was done, and on level ground farther north



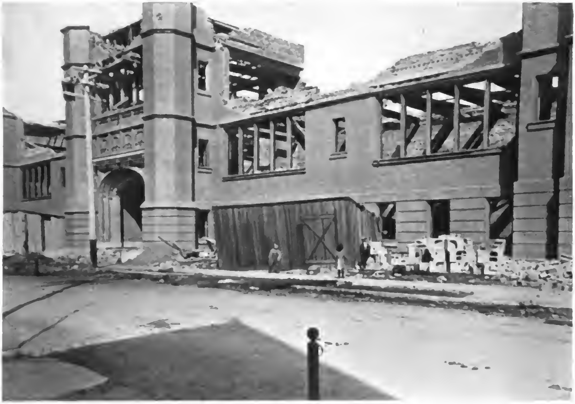
A. Oakland. Central Bank Building. G. K. G.



B. Oakland. Smokestack of power plant, Oakland Traction Company. A. S. E.

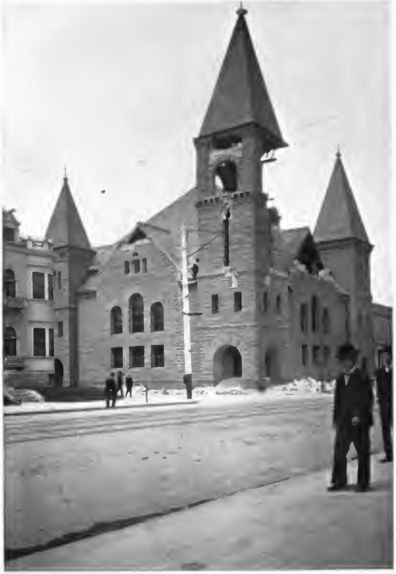


A. Oakland. Flax works, Union and Third Streets. A. S. E.

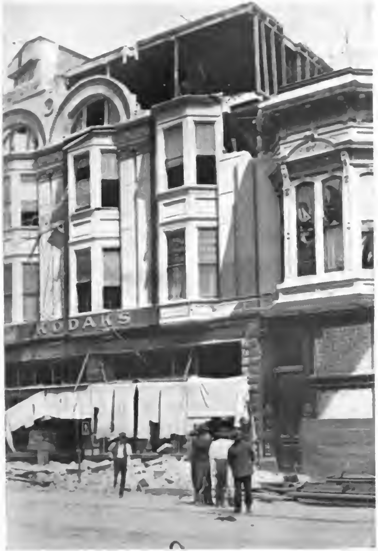


B. Oakland. Prescott School, Ninth and Campbell Streets. A. S. E.

PLATE 122



A. Oakland. First Baptist Church, Telegraph Avenue. G. K. G.



B. Oakland. Fourteenth Street, between Washington and Broadway.

absolutely no monuments were affected. Near the top of the ridge many monuments were overturned, and nearly all of them showed twisting or shifting. The result of the shock upon the monuments in this cemetery may be summarily stated as follows:

Fifteen were rotated counter-clockwise, 4 of these thru from 1° to 2°; 6 thru 5°; 1 thru 15°; 3 thru from 5° to 8° with a lateral shift of 1 inch to the east; and 1 thru 8° with a lateral shift to the south.

Six were rotated clockwise, 2 of them thru 25° to 30°; 1 thru 15°; 1 thru 10° with a lateral shift of 6 inches to the south; and 2 thru 2° with a shift to the south of 1 inch.

Six fell to the east, 1 to the west, and 1 to the north.

Three were shifted laterally from 0.5 to 1 inch to the east, one 1 inch to the southwest, and one 1 inch to the south.

(B. McGregor.)—Of 12 monuments in Mountain View Cemetery that were disturbed by the earthquake, 10 are rectangular shafts which were simply twisted on their bases, 4 from left to right and 6 from right to left. The other 2 are turned shafts, both of which slid on their bases about 2 inches south. There were a few others displaced.

Alameda. — The destruction was confined for the most part to the throw of chimneys and the upper portions of brick walls. A few tanks were also overthrown, and 3 large stacks near Pacific Avenue and Lina Street. Messrs. Pond and McFarland counted 619 fallen chimneys in the city; of these they report that 189 fell to the southwest, 143 to the southeast, 93 to the northwest, 97 to the northeast, 34 to the south, 14 to the north, 25 to the east, and 24 to the west.

The fall of chimneys was evidently determined largely by the orientation of the houses, which have their walls in nearly all cases orientated at right angles to the direction given for the fall. The statistics are quoted not because they have any special significance, but because they indicate how little this class of phenomena contributes to the elucidation of the character of the earth movement, unless each particular case is studied in all its bearings.

With regard to the chimneys which were dislocated and twisted, there appears to be more constancy of result. The same gentlemen counted 61 such chimneys and of these 58 were rotated counter-clockwise and 3 clockwise.

Southeast of Oakland (G. Backus and R. P. O. Newcomb). — In the vicinity of High Street about half of the chimneys fell. The most general direction of the fall was to the north and south, altho some fell east and west when the slope of the roof was in that direction. Plastering in the houses was severely cracked, but no foundations nor buildings were damaged to any visible extent. A large smelter chimney in the vicinity was not damaged by the shock.

At Fitchburg about the same state of damage was seen. The chimneys on the old houses were gone. A large school-house with a brick foundation was not injured.

At Elmhurst the windows in the hotels and stores were broken. Most of the chimneys had fallen, one in particular being thrown to the east against the slope of the roof.

At San Leandro half the windows in the stores were broken, and nearly every chimney was down. All loose objects in the houses, such as dishes, etc., were thrown down. The plastering was greatly cracked. The houses were not seriously damaged, and only 2 have been condemned.

At Junction City the shock was about the same as at San Leandro. According to rumor a 3-inch fissure opened up between Junction and San Lorenzo, but this was not seen.

The County Hospital, but a short distance from the Junction, was only slightly damaged. None of the chimneys were thrown over and plastering was not cracked. The Hospital is built on solid ground, and several quarries can be seen in the ground upon which the buildings are situated.

At the San Lorenzo Cemetery, about half the tall monuments were down. Most of these fell to the south, some to the north, and a few to the east and west. Twisting occurs where the south end is thrown east. Almost all the chimneys in this vicinity were down.

At Mills College about half the chimneys were down. A stone building there was badly shattered and will have to be taken down. A brick and concrete library, and the same kind of a bell-tower, were not injured to any great extent, tho a few cracks can be seen here and there. Mills is on rather high ground at the base of the foot-hills.

(J. Keep.)—The floor of my room at Mills College seemed to be boiling. Immense damage was done. In the made ground there was a drop of from 1 foot to several feet. The seismograph registered for a time and then broke. The Science Hall, a stone structure, was badly injured, entailing a loss of $5,000.

(J. N. Frank.)—In San Leandro objects against the east and west walls of the house were thrown down. Some statues were rotated clockwise. Chimneys were overthrown or broken, and plaster cracked, causing a damage estimated at between $400 and $500.

Mount Eden (William Gall). — The general direction of the movement was to the north and northeast, but objects fell in all directions. Objects were rotated, some clockwise and some counter-clockwise. A rotary motion was distinctly felt. Brick chimneys were broken and thrown. Furniture was thrown flat. The shock caused consternation among the people and domestic animals. Monuments in the cemetery were overthrown in various directions.

Decoto (F. E. Matthes). — No earth movements nor displacements were discovered anywhere along the base of the mountain scarp. The damage to buildings was slight, consisting of broken or twisted chimneys and cracking of plaster in a few houses. A few scattering chimneys escaped destruction, being probably better built than the average. In the stores and saloons articles were thrown down in southerly directions for the most part. Water was observed to splash from a tank a mile north of town, the direction of throw being southeasterly. The consensus of opinion was that the shock had a nearly north-south direction. According to the track-boss, the railroad track suffered no displacements anywhere between Niles and Irvington. The Masonic Home, a large brick structure located on the hillside on solid rock foundations, suffered but little damage. A few insignificant cracks in the brick walls, 2 chimneys broken off, and 2 chimneys cracked constitute the most serious damage. Plaster was cracked in several rooms; no windows were broken.

Alvarado (F. E. Matthes). — The Alameda Sugar Company was the chief sufferer. The main buildings of the plant are of wood, substantially constructed, and were not damaged; but the fittings and accessory structures were injured in numerous places. An old lime-kiln showed diagonal cracks in the brickwork; several of the small arches above the fire holes opened and let bricks fall out. A 6-inch cast-iron water-pipe, attached vertically to the main building, broke transversely about 30 feet above the ground. The water in the tanks on the roof splashed so heavily as to raise and break the wooden covers. The water seems to have splashed mostly to the east. The 2 great platforms carrying the molasses tanks, supported by numerous vertical props 10 feet 10 inches high, resting on concrete foundations, fell down altogether; the northern one to the north, the southern one to the south, these directions probably being determined by the original inclination of the supports or the relative efficiency of the bracing. The tanks were all damaged and over 1,000,000 pounds of molasses flowed away. The total weight on the south platform was 1,072,891 pounds. (Plate 115A.) In the engine-room the vertical steam-pipes cracked next to the flanges by the wracking motion of the ceilings thru which they extended. The shock appears to have had a north-south direction, according to the position of the breaks in these pipes.

The mill stands on flat, alluvial ground 100 feet north of Alameda Creek. Along the banks of the latter a large number of cracks extend, roughly parallel with the stream. Considerable masses next to the stream-bed slumped toward the same, leaving gaping cracks 1 to 2 feet wide, and carrying with them small outlying buildings, notably the fire-engine house, which moved bodily, concrete foundation and all, 2 feet south toward the creek. A small railroad trestle southwest of the mill moved 4 inches south on both of its abutments, probably owing to slumping of loose ground on the north side of the creek. A 2-inch water-pipe, laid under the ground some 60 feet north of the creek and almost parallel with the same, shows indications of having been submitted first to tension, causing rupture at one of the joints, then to sudden compression, causing it to be jammed together with violence.

Cracks in the ground may be found as far as 250 feet from the creek. They were nearly all closed at the time of the visit (May 7), but were easily traced by the streaks of bluish-gray sand which has issued from them, together with considerable quantities of water. According to the Chinese cook of the superintendent, the cracks nearest to his dwelling opened and closed several times in succession during the quake; and large volumes of mud-laden water gushed from them, splashing up some 10 feet in the air at each closing. A large crack of this kind opened under the northwest corner of the dwelling, and the superintendent estimates that fully 500 gallons of water gushed from it, the flow continuing with decreasing volume for about an hour. The fence in front of the house shows that the ground there has been raised into a low hump. The sewer pipe leading west to the creek was detached from the house by a space of 22 inches. A chimney near the northeast corner of the house was thrown to the east with sufficient violence to throw the farthest bricks 35 feet east of the house. The top of the chimney was only 20 feet above the ground originally.

In the roadway south of the mill, water oozed out in a number of places, without the production of visible cracks. The water pipes and hydrants in this vicinity were crusht in several places.

At the Alvarado Water Works the brick buildings suffered considerable damage, the walls cracking in several places. Nothing could be learned regarding the behavior of the wells of this plant. The frame dwelling of the superintendent was damaged by the collapse of its underpinning. A similar fate befell the Alvarado Hotel. Both houses were being put in place at the date of the visit. At the school-house the water-tank fell owing to the collapse of its supports.

Nearly all brick chimneys in the village fell, the directions varying. A few cracks opened across the streets, but these had been filled on the date of the visit. The consensus of opinion was that the shock had a north-south direction.

Lick Observatory, Mount Hamilton. — From the reports of astronomers C. D. Perrine, R. G. Aitken, H. K. Palmer, K. Burns, A. M. Hobe, and G. A. Vogt the following observations as to the character and intensity of the shock have been obtained. The principal disturbance was preceded by a tremulous motion variously estimated at from 11 to 15 or 20 seconds. There seemed to be 2 maxima, the first being the stronger (?), according to H. K. P. There was a first secondary maximum about 5 seconds after the beginning, a maximum 11 seconds after the beginning, and another secondary maximum about 15 or 20 seconds after the beginning, according to K. B.

A tremulous motion was felt after the principal disturbance.

"Heavy vibrations were still felt 60 seconds after the first count. Motion was felt for nearly 2 minutes after the first count." C. D. P. "The duration of this tremulous motion was about 30 seconds. Vibrations stopt in the house at the end of that time." K. B.

"Duration between 30 and 35 seconds." A. M. H.

No vertical motion was perceived, nor was any recorded on the Ewing seismograph.

According to C. D. P., the heaviest movement seemed to be nearly east and west, while according to K. B. it was northwest and southeast. On the Ewing seismogram, the north and south component seems to be the most violent, the pen having left the plate for half a revolution of the plate. The east and west vibration was extremely large. The maximum of the east and west movement occurred after the pen of the north and south component left the plate.

A razor strop hanging on a north wall, the only thing free to swing, swung east and west about a foot (double amplitude). A shaving brush which stood up on end and, being round, could fall in any direction, fell west. Things overturned fell east and west.

The shock was severe enough to make windows rattle and doors swing. Book-cases were moved out about an inch from east and west walls, but not from north and south walls. A pendulum clock on a north wall stopt at $5^h\ 12^m\ 52^s$. Not much plaster fell, and only 1 of a dozen or more chimneys was thrown. Some other chimneys, principally those of a 3-story brick house, were cracked and shifted.

The earth-waves were very long, but smooth.

According to K. B., the shock was accompanied by a sound as of the flight of birds.

The water in Smith Creek on the afternoon of the day of the shock was of a light slate color; not yellowish, as after heavy freshets.

"Standing in the doorway and looking out the east window, I could see the walls of the brick house shaking. There seemed to be a great deal of dust in the air in front of the window." H. K. P.

The movement of the east-west component of the Ewing seismograph indicates an intensity corresponding to an acceleration of 400 mm. per sec. per sec. The north and south pen left the plate, owing to the violence of the shock.

Niles (R. Crandall). — The town of Niles stands on gravels of the alluvial fan at the mouth of the Niles Canyon, and is about 20 miles due east of the fault at its nearest point. At Niles there were no large buildings, and most of the structures were not strong, but there was no serious damage done to any of them. About 56 per cent of the houses had either terra-cotta chimneys or tin pipes, which are much harder to shake down than those of brick. Of all the chimneys in town, 48 per cent fell; of the brick chimneys 80 per cent fell; of the terra-cotta chimneys only 10 per cent went down.

Most of the houses were not plastered, so no notes could be obtained on that subject. In nearly all of the houses such objects as dishes, bottles, vases, and clocks were thrown from the shelves. Milk and water were spilt from open receptacles in most cases.

A concrete abutment of the bridge across Alameda Creek was cracked. A man out of doors at the time found much difficulty in walking. A 50,000-gallon water-tank fell at the Niles railway station. Similar tanks were thrown down at the stations at Pleasanton, Livermore, and Lathrop. This was due to imperfect construction rather than to the violence of the shock. The tanks were upon cast-iron pillars originally, but when new and larger locomotives were put into service on the railway, it was found necessary to have the water-tanks set higher. This was accomplished by inserting short blocks between the tanks and the tops of the pillars. When the weight of 200 tons was swayed on this sort of a structure, the tank collapsed.

While at Niles, a visit was made to one of the new tunnels of the Western Pacific Railway, which is about 1 mile east of Niles in the Niles Canyon. The tunnel had penetrated about 130 feet into the hillside, but had not yet past thru anything but a sandy clay. During the previous winter the walls at the portal, and also on the inside, had stood without timbering. Since the earthquake it had been impossible to break out more than 4 feet of ground ahead of the timber sets without caving taking place. There had been an apparent movement in the soil which had removed its consistency and made it incoherent. The amount of water present in the tunnel was perceptibly changed. The foreman said that there was more water since the shock than there had been even in the wettest part of the winter.

Sunol (R. Crandall). — Sunol is a small town in the north end of Sunol Valley. The intensity of the earthquake there was of especial interest, because the town lies almost upon the line of the Sunol fault. This fault is the largest one known in the Mount Hamilton range, and has a northwest-southeast trend parallel to that of the San Andreas fault. It was expected that some compensating movement might be found to offset the slip along the San Andreas fault, and this Sunol fault was considered the one most likely to show that compensatory movement. The town stands partly on gravels and partly upon hard sandstone. The gravels are quite firm; much more so than the gravels on which the town of Niles is built. The gravels at Sunol are not thick, and the foundation is much firmer than that at Niles. It was quite apparent that Sunol had not felt the shock as severely as it had been felt at Niles, 6 miles to the west, or at Pleasanton, 6 miles farther east. Only a small percentage of the chimneys fell. Of other objects, few except bottles and vases fell; and a window was broken at the post-office. As there was no movement along the Sunol fault, the intensity at Sunol was less than at Niles, but the fact that it was also less than at Pleasanton shows that the difference must be in the formations underlying the two towns.

(F. E. Matthes.) — Over 75 per cent of the chimneys in Sunol were broken. Some were twisted in a clockwise direction, while others were apparently thrown straight, most of them to the east. Many chimneys were cracked but were still in place. A few windows were broken, notably those of the post-office. The town is on alluvial ground, close to the hills. The depth of alluvium is estimated at the creek-bed to be about 50 feet. The steel bridge southeast of the town was found entirely undamaged. The flume between Sunol and Niles was damaged at a point 2.5 miles below Sunol. A few boards were knocked out of place, but the damage was slight and quickly repaired. The Apperson house, a substantially built structure with strong chimneys, had two of the chimneys twisted and one left intact.

Verona (F. E. Matthes). — All the chimneys on the main house of the Hearst residence, 6 in number, were cracked, but none was thrown down. The studio has a long crack running immediately above the projecting beams supporting the roof, along the northeast wall, 18 inches from the eaves. No damage was occasioned to plaster or walls, except in the studio. The chimney of the power-plant, at the foot of the hill, was found cracked. The "cottage," built of wood, suffered no damage. No windows were broken.

Pleasanton (R. Crandall). — The town is on a flat valley-floor composed of gravels, apparently the same as those at Sunol, but of a later age. Probably the Sunol gravels washt down from the hills to form a valley-floor. The ground upon which the town is built, then, is similar to that at Niles. The shock was felt quite sharply at Pleasanton, but not so much so as at Niles. Such articles as vases, clocks, and dishes fell in most cases and milk and water were spilt from open vessels. Practically no plaster fell, but houses that were plastered had numerous cracks in the walls.

The intensity, as shown by falling chimneys, was as follows: 30 per cent of all chimneys fell; 48 per cent of the brick chimneys fell; 30 per cent of the chimneys were terra-cotta, but only 3 per cent of these fell; of the brick chimneys which did not fall, 30 per cent were cracked.

(F. E. Matthes.) — About 50 per cent of all brick and tile chimneys in Pleasanton were thrown down. No marked preponderance in any one direction was noted. Nearly every brick building in town was somewhat injured. Cracks in the masonry and the dislodgment of occasional individual bricks in arches above windows and cornices constitute the principal damage. The only stone house, a 2-story saloon, suffered more severely than any of the brick buildings, the walls being badly cracked at the corners and even partly thrown down at the northwest corner. Wooden houses suffered no damage except the cracking of plaster. No window panes were broken.

Two bridges near Pleasanton were inspected, one north of the town over Arroyo Valley and the other over Arroyo de la Laguna, 1.5 miles west of the town. These bridges rest on concrete abutments, and examination showed that in both cases the concrete had sheared horizontally by the longitudinal oscillations of the superstructure. The cracks were about even with the lower side of the stringers. In the case of the first bridge mentioned, these cracks extended to the wing wall at the south end. A vertical crack was also found near the west corner of the south abutment, running thru the entire height of the structure. A similar crack was also found at the east corner of the north abutment. The disposition of these vertical cracks seems to indicate torsional movements of the bridge, with right-handed rotation. The concrete was of poor quality, being traversed by streaks of coarse gravel alternating with others of finer texture.

Thru the courtesy of F. H. Tibbets and Harold Woods, surveyors for the Pleasanton Hop Company, access was obtained to their records on well borings made in the neighborhood of Pleasanton. Most of these borings did not reach bedrock, but 2 of them did: one near the graveyard south of Pleasanton, which strikes disintegrated shales at a depth of 275 feet; the other 0.75 mile northeast of Pleasanton, just south of the railroad track, which strikes similar material at a depth of 180 feet.

Livermore (F. E. Matthes). — Many chimneys were cracked and about 50 per cent thrown down. Several tall brick chimneys in various parts of the town were left intact. Those on brick piers between Livermore and Pleasanton were undamaged. A block of old, weak-looking buildings northeast of the depot suffered no more than a few cracks. Glassware in saloons and bars was thrown to the floor in quantities, in various directions. A heavy water-tank at the depot fell, owing to weakness of supports. The direction of the fall is north, but this is not necessarily indicative of the direction of the shock, as the wooden support probably gave way piecemeal. Concrete bridges about town were unhurt. The town is on alluvium.

An interesting feature appears 0.25 mile north of Meyn's ranch, west of the road leading north from Livermore, about 2 miles north of that place. It is on the summit of a smoothly rounded hill, sloping gently down to an even, peaty meadow traversed by the arroyo of Cayetana Creek. The hill is really one of a number of spurs of the higher land south of the meadow. Its soil is peaty, with many sun cracks due to recent drying. Deep cattle tracks show that it must be quite soft in wet weather, much like the adjoining meadow. The summit of the hill in question was found crowned by a series of concentric deformations, rising stepwise above one another. A number of nearly concentric cracks were found extending northward into a sort of panhandle, along each of which an upward movement of the soil had apparently taken place. The uplift along the 2 principal cracks was found to be 19 and 16 inches, respectively. Along the minor cracks the vertical displacement amounted to an inch or two only. The surface of each step or bench was found to slope inward, and in some places the edge even appeared to have curled inward. The material must have been wet and more or less plastic at the time of the disturbance, but has since dried and hardened, as peaty soil will in dry weather. While the phenomenon is described by many as a "mud flow" or "mud spring," there are no indications whatever of a "flow," strictly speaking. The inward slope of the raised benches suggests the dropping back of the central portions after their upheaval; the scarps remaining, probably, owing to the friction between the opposite walls of the fissures, which prevented the complete return of the adjoining edges to their former level. The concentric arrangement of the cracks seems to indicate a centralized upward thrust, and the small diameter of the entire deformation shows that the effect of the thrust rapidly decreased away from the center. While there is no rock visible, it is quite possible that the hill has a sort of rock-core, some distance below the surface. The shock felt at Meyn's ranch was not particularly violent and caused no damage to the buildings. (See plate 141A.)

(R. Crandall.)—Geologically, Livermore is on a floor similar to that of Pleasanton, but geographically it is about 6 miles farther east and farther from the San Andreas fault. The shock at Livermore was not severe, and but little real damage was done. A few objects of unstable nature fell, and in the larger number of cases milk and water were spilt from open vessels, but not in all cases.[1] Most of the houses in town were not plastered, but only a few of the plastered houses had the walls cracked, and in only one case was plaster known to have fallen.

An excellent opportunity was afforded to see the effect of the motion upon pendulum clocks. In one jewelry store every such clock stopt, regardless of the direction in which the pendulum swung. One clock which had not been running before the earthquake, was started. Its pendulum swung in a northwest-southeast direction, as in the case of several clocks that stopt. About 5 per cent of the brick chimneys fell, with less than 15 per cent cracked.

A curious phenomenon was observed near Livermore, the explanation of which is not clear. At the Alviso ranch, a little over a mile north of the town, the top of a small hill was broken up at the time of the earthquake. The breaking of the ground did not consist of fissuring along a line, but was in the nature of an uplift of a limited area. There were 3 fairly well marked concentric rings where the ground had broken, the inside ring in each case being forced higher than the outside ring. The effect was similar to that obtained by placing 3 plates of different sizes within each other. The accompanying photograph (plate 141A) shows this feature fairly well. It was said by people in the vicinity that there was mud in the cracks at the time of the earthquake, but there were no evidences of any at the time of the writer's visit several weeks after the shock.[2]

(Elmer G. Still.)—The Southern Pacific Company's 20,000-gallon water-tank fell in a north-northwest direction; tombstones fell in various directions; a hanging lamp was caused to swing counter-clockwise, with the longer diameter of its orbit east and west. Mr. Still was asleep and was awakened by the bed being shaken north and south; the motion after that was in every direction. Water spilt from full tanks mostly on the east and west sides. Mr. Still reports that where the ground was deformed in concentric ridges, as described by Mr. Matthes and Mr. Crandall, there was an alkaline spring years ago.

Santa Rita, 3 miles east of Dublin (F. E. Matthes). — A small, flat levee along the east bank of Tassajara Creek, immediately north of the main road, showed several somewhat crescentic cracks along which the ground had slipt down and toward the creek from 1 to 3 inches. These cracks extended farther south, according to local settlers, and crost the road; but this was no longer traceable at the time of the visit. Chimneys had fallen on all the houses, but as they were not of brick the damage was slight. In the grocery store and bar-room articles were thrown in a southerly direction.

Dublin (F. E. Matthes). — The damage consisted of a few chimneys broken off, and articles thrown down from shelves and counters. A water-tank 2 miles east fell from its supports, probably owing to the weakness of the latter. Several other tanks in the neighborhood were injured.

San Ramon (F. E. Matthes). — Most chimneys had fallen. San Ramon saloon, south of the bridge, slid off its foundations in a northerly direction. The west end moved 3 feet, the east end about 15 inches, being stopt by a fence-post. Several window panes were broken in the building, and glassware was wrecked in quantities. Neither church nor school-house suffered any damage. The shock was mostly in a north-south direction.

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[1] This may be contrasted with Pleasanton, where at all the houses visited there was only one where milk was not spilt.

[2] A somewhat similar phenomenon was seen on Cahill's ridge in San Mateo County, but there was nothing to suggest an explanation.

Danville (F. E. Matthes). — Most chimneys were cracked or twisted; a few were broken off completely. Glassware in saloons and goods in a grocery store were thrown down in quantities in various directions. Water was observed to splash out from two tanks in the village, in a southerly direction in each case. Water-pipes laid over the surface of the ground at a neighboring ranch were reported to have been thrown out of alinement.

Walnut Creek (F. E. Matthes). — About 50 per cent of all chimneys were thrown down. A water-tank at the livery stable fell. Goods in the grocery store were thrown down in quantities. The direction of the shock was not ascertainable. Two barns, weak structures, were moved slightly from their foundations. Plaster in several houses was cracked.

Clayton (G. D. Louderback). — At the northern base of Mount Diablo the intensity of the shock was much less than in the alluviated valley-bottom at Concord. No chimneys were thrown down, and no dishes nor glassware were knocked off shelves, but milk in pans was skimmed by the rocking motion. On a hillside above Peach Tree Spring, on the west side of Mount Diablo and very near the contact of the Knoxville shales and the Franciscan, a crack opened in the ground about 30 feet long, in a north and south direction, gaping 4.5 inches.

Concord (F. E. Matthes). — Conditions here were much the same as at Walnut Creek. The only brick building, a bank, was cracked. Most of the chimneys were cracked, and about 50 per cent had fallen. A water-tank at the depot was thrown down.

Martinez (F. E. Matthes). — Most of the brick buildings here suffered severely; nearly all are more or less cracked, and the stone facing of several was partly demolished. The roofs of the bank and other buildings were wrecked. A small stone house, built of large blocks, was completely ruined, probably owing to vigorous vibrations of an adjoining wooden water-tower near the Alhambra Hotel. The stones started in the east abutment of Main Street bridge. Many window-panes were broken. Most of the chimneys were broken off. The court-house was little injured, except for the pediment above the entrance, where many large stones have been loosened. One of the chimneys of the Bull's Head Oil Works lost a corner; the others were left undamaged. The railroad track east of Martinez, near Bull's Head Oil Works, was thrown 3 inches out of alinement to the north. Many cracks occurred in the embankment on both sides of the track. A series of 5 small transverse waves was found in the embankment about 0.5 mile west of Peyton Station. The distance between crests was about 10 to 15 feet; amplitude estimated at 3 inches. This embankment lies in flat marshy land. A small railroad bridge near Avon Station was thrown 4 inches toward the east abutment, but it had been repaired at the time of the visit.

(W. Stoddard.)—Buildings were loosened in general, the fronts of some falling out. The north and south walls seemed to suffer most. Parts of a large wooden building, particularly the window-sashes, were moved in a southwesterly direction. The wooden props supporting another building were tilted a little toward the southwest. Another building was moved 0.5 inch toward the south. The southern part of the town was damaged more than the northern part. In the cemetery 6 slabs and pillars fell a little east of north; 2 pillars fell to the west; 2 pillars were twisted on their bases and shifted to the west; 1 pillar was tilted to the south immediately next one which fell to the east. A clock at the court-house had its pendulum broken. The pendulum was about 2 feet long. The level of the underground water rose after the shock.

Cornwall and Black Diamond (E. S. Larsen). — The towns are about 0.5 mile apart, both located on the bay flat and underlain by a tough hardpan. A very few things were thrown from shelves; one rickety chimney was thrown, and one concrete wall in process of construction fell. Less than half the clocks were stopt, though nearly all sleepers were awakened. Most of the houses are small and have terra-cotta chimneys.

Antioch (E. S. Larsen). — Antioch is on the same sort of ground as Cornwall, but there are more brick buildings and more moderate-sized buildings with brick chimneys. A few chimneys were twisted on their bases, several were thrown entirely and about 25 per cent of them needed repairing after the shock. Out of about 12 brick buildings, the tower of the Catholic church was somewhat damaged, and one rickety old brick building fell. None of the good buildings were damaged. A couple of windows were broken, a few clocks were stopt, and a few things were thrown from shelves. Top-heavy statuettes tipt over. All sleepers were awakened. Things generally moved north and south, or northwest and southeast, which seemed to be the general impression of the direction.

Bethany, San Joaquin County (Mr. Schichtman). — The movement was from northeast to southwest, and was sufficient to splash water from a full trough, but not strong enough to overthrow objects.

Byron Hot Springs, Contra Costa County. — The springs, some 30 in number, hot and cold, were not affected by the earthquake. One chimney and some plaster were cracked and a picture was thrown from the wall. The shock was considered quite severe, though the damage was slight.

Tracy (R. Crandall). — Tracy, in the San Joaquin Valley, lies at the foot of the range separating Livermore Valley from San Joaquin Valley. The shock was not at all severe; in fact it was spoken of by several as being no heavier than the jarring often occasioned by heavy engines starting a loaded train. Very few objects fell, and in only one case was any damage done to a building. This was the cracking of a 2-story brick building which did not appear to be especially well constructed. Only one brick chimney cracked, and none fell; so it would appear that the building cracked because of the poor construction rather than because of the intensity of the earthquake. Milk or water was spilt in only few cases — not over 30 per cent. The water-tank of the Southern Pacific railroad at Tracy fell, as did similar tanks at Livermore, Pleasanton, and Lathrop. The reason for this is explained in the description on a preceding page of the construction of the tank supports at Niles.

Lathrop (R. Crandall). — This is a small town upon the floor of the San Joaquin Valley, about 12 miles east of Tracy. The intensity was about the same as at Tracy. There was no appreciable difference in the number of fallen objects or stopt clocks, the main difference being that a considerable number of people were not alarmed enough to get up. One man who was up experienced no difficulty in standing or walking. The general impression is that the shock was slightly lighter than at Tracy.

Stockton (R. Crandall). — Stockton is about 10 miles north of Lathrop, but not much farther east. As it is a much larger place, it was easier to see the effects of the earthquake. Not as much detailed work was done in Stockton as at the other places, since it was known that Mr. Edward Hughes was collecting data in that city. The shock was felt with alarm by people in houses and on the ground. The motion was spoken of as being a rolling motion like that felt on board ship. Almost no objects fell, even in houses where there were tall vases and similar bric-à-brac. At one drug store two little vials fell from the shelves; at another even built-up pyramids of various articles for window display were undisturbed. Milk and water were spilt in a very few cases. Splashing of milk up the sides of the pans was noted by a few persons, and the direction was given as northwest and southeast. Many clocks were stopt, but there was nothing consistent in the direction of pendulum motion. All of the big brick buildings were visited, and no damage was found except in an old 2-story building which seemed merely to have had an old crack widened, due to the settling of the foundation. The City Hall had considerable plaster cracked, but this was due to the swaying of a 50,000-gallon tank on the roof. Three chimneys were cracked, and one was reported to have fallen, but this was not verified. At the houses where the chimneys were cracked, milk was not spilt from open pans, so it is apparent that the chimneys were faulty and not that the earthquake was severe.

(E. Hughes.)—A careful and exhaustive inquiry was made at Stockton by Mr. Edward Hughes, under the direction of Prof. J. C. Branner, and the following notes are contributed by him:

The shock, while strong enough to alarm many of our people, was chiefly notable for the absence of the destructive effects experienced in many less fortunate localities. It began with a gentle trembling motion, which increased slowly for the first 5 or 6 seconds, then rapidly to a maximum of rough jolting shocks lasting perhaps 5 seconds. These were followed by a series of long, smooth vibrations, which gradually decreased in amplitude until no longer perceptible. The effects, as noted by many observers, would indicate that the heavier shocks traveled in a northwest-southeast direction, while the smooth oscillations which marked the latter part of the disturbance ran nearly east-west. The immediate effects, as noted in dwellings, during the shock were the creaking and straining of buildings, the swinging of doors, the rattling of window weights and pictures on the walls, the swinging of chandeliers and drop-lights, and the stopping of clocks. Out of doors, some observers claim to have noticed the swaying of tall buildings and smoke-stacks; and many mention the violent motion of the trees, the branches of which lasht together as if in a storm. Birds frightened from their resting places flew in confusion, and the air was filled with their startled cries.

A careful canvass of the city gives the following results in the way of damages sustained: There were a few small cracks in the arches in the hallways of the county courthouse. It is safe to attribute this to faulty construction rather than to the violence of the shock, as a number of large cracks had opened in various parts of the building soon after it was finished. One water-tank was overturned, the supporting framework being insufficiently braced; this tank fell about 15° east of south.

A large gasometer at the natural gas well on north Commerce Street was slightly damaged. Castings supporting the guide wheels were broken, and the gas tank was slightly twisted to the left so that the guide wheels were thrown off the guides.

In two or three cases in the city, the tops of chimneys fell off. Examination showed that the mortar had never properly united with the bricks, owing probably to their dryness when laid. In several cases houses suffered damage by the spilling of water from attic tanks.

Aside from these cases of relatively insignificant damage, everything gives testimony to the comparative gentleness of the shock. In china stores, where fragile wares were displayed in all sorts of insecure positions, not a piece was displaced or broken. So far as can be learned, no plaster fell anywhere in the city, and there was no breakage of bric-à-brac or china in the dwellings. Observers who watched the minute hands of clocks that were not stopt estimate the duration of the shock at from 30 to 40 seconds.

The heavier shocks were undoubtedly from northwest to southeast. This was shown in several ways. Tanks spilt water in both these directions, and the tank noted above fell nearly to the southeast, although its frame ran approximately east and west, and so offered some resistance to free motion to the southeast. In McCloud's Lake, the waves ran northwest-southeast, breaking highest on the bank and bulkhead in the southeast corner, while the north side was little affected. At the city pumping station on Mormon Channel, a similar effect was noted. Several observers claim to have seen tall buildings and stacks swaying in the direction indicated, and those who were standing were conscious of the movement of their own bodies in the same direction. Milk in open vessels left a coating of cream highest on the northwest and southeast sides, although in many cases motion was also shown east and west.

While there is not entire agreement with reference to the east and west vibrations during the latter part of the shock, the larger number of observers plainly felt and saw their effects, and the evidence as to their occurrence seems conclusive. Doors swung east and west; swinging objects, such as drop-lights, hanging baskets, etc., were found either swinging east and west or in circles after the shock, and pictures hung on north and south walls of rooms showed lateral motion during the latter part of it. Tanks in several cases spilt water east and west, although not in such quantities as in the other directions.

The following table indicates the effect of the shock on the 128 clocks concerning which reports were received:

Orientation.	Number of Clocks.	Stopt.	Not Stopt.
Facing west . .	32	17	15
Facing north . .	36	18	18
Facing east . .	27	13	14
Facing south . .	33	16	17
Total . . .	128	64	64

Clocks with very long or very short pendulums were generally not stopt. Two town clocks were not stopt. One of these, which, through the courtesy of Mr. E. B. Condy, I was permitted to examine, is in the tower of the county court-house. Its frame stands northeast and southwest; and its 100-pound pendulum, hung on the northwest side of the frame, swings northeast and southwest, missing the edge of the iron stand about 0.5 inch. A deep scar in the mahogany pendulum bar indicates that during the shock the pendulum swung sharply to the southeast, its bar striking the edge of the iron stand. The weights of the same clock hang in a narrow shaft at the side of the tower. The wire pulley cords which support the weights were found so badly twisted as to interfere with winding the clock a day or two after the earthquake. On the inside of many clock-cases are found scars made by the striking of the pendulums. These scars are deepest on the south side in clocks facing east or west, and on the west side in clocks facing north or south.

Some persons who were outdoors during the shock claim to have heard a dull rumbling sound immediately preceding it. They find it difficult to describe the sound accurately, and in some cases think it may have emanated from nearby buildings. A considerable number of people suffered from nausea and dizziness, with headache, for a time after the shock. With some these disagreeable symptoms persisted all the following day.

Farmington, San Joaquin County (J. F. Gwin). — The house quivered, then the sash weights of the windows began striking back and forth, and a heavy rolling motion was felt which caused open doors to swing back and forth. The clock stopt. The surface of the ground moved in waves like water, and trees moved with the ground.

Central San Joaquin County (E. P. Higby). — In Ranges 6 and 7 E., townships 1 and 2 N., Mount Diablo Meridian and Base line, there were apparently 2 maxima of equal intensity with intervals of a few seconds between. The apparent direction was SW. to NE. No objects nor chimneys were overthrown. The bed shook, and chandeliers, pictures, open doors and shutters were caused to swing. Windows and window weights rattled. The clock did not stop. Paper on the walls was cracked. The slate roof on a high church tower was cracked. There was scarcely a breath of wind, yet large trees swayed and bent as if rocked by a terrible gale. Water in the wind-mill tank and in other tanks slopt over, and continued to do so for 5 minutes after the shock. Water was thrown from a swimming tank where the level was 5 feet below the top of the tank; water at one place in the river was thrown over a concrete wall 8 or 9 feet high.

Modesto (E. Hughes). — In common with other points in the great interior valley region, Modesto received a very decided shaking up by the earthquake, but suffered practically no damage. The local effects were the stopping of clocks, the swaying of trees, hanging baskets, drop-lights, and chandeliers; and in a few cases the fall of objects from insecure positions in stores and dwellings. Water tanks and troughs, milk pans, etc., spilt part of their contents, and in one or two instances cracks opened in buildings. No one, so far as known, actually timed the duration of the shock in seconds.

The observations of many persons in and near the town indicate that the vibrations were in two principal directions: viz., northwest-southeast and approximately west-east. The heavier shock seems to have been in the first direction, but observers are not in entire agreement on this point. Clocks of larger size were quite generally stopt, no matter in what direction they faced. Several persons report having heard a roaring or rumbling sound, beginning a few seconds before and continuing until the end of the disturbance; and a number of people were affected by symptoms somewhat like seasickness for several hours after it.

The following detailed notes were obtained from citizens of Modesto and vicinity:

(Mr. Schaffer.)—Trees swayed northwest-southeast. "The Swan," a new building with green walls, cracked at the junction of the ceiling with the northeast end wall; also at the junction of the ceiling with the fire-wall running thru the center of the building from northwest to southeast. The cracks in both cases were on the second (the top) floor. The building faces northwest.

(Player's Drug Store.)—Boxes on shelves on the northwest side of the store fell toward the southeast.

(Mr. Swanson.)—Saw water spilt southeast-northwest from the railway tank at the depot.

(Al Fogarty.)—Meat market. Mr. Fogarty ran from the building, and on returning after the shock he found drop-lights and a butchers' scale, suspended by a single wire from the ceiling, swinging in a direction parallel with the street, northwest-southeast.

(Green Brothers.)—Heard a roaring sound just before the shock. Felt the bed swing northwest-southeast. Plaster sifted down from cracks in the ceiling.

(E. E. Woods.)—Mirror hanging from southeast wall fell, on account of breaking of the cord, on its face toward the northwest.

(Mr. Chapman.)—Ranch 5 miles southwest of Modesto. Water trough oriented north-south spilt water from both ends.

(George T. McCabe.)—The bed was standing north-south. The first motion was east-west, the second and maximum motion was northwest-southeast. Trees swayed northwest-southeast. The window sash dropt.

(Mr. Rider.)—Water in the street gutters moved west-east in the first part of the shock; in the second part, northwest-southeast.

(Mr. Schaffer.)—Twenty-one miles southeast of Modesto. The sliding doors on a barn fronting east moved north and south repeatedly during the shock. A water trough a few feet away spilt water east and west.

(Johnson and Ross Store.)—A pile of paint cans stood northwest-southeast. Several cans fell to the northeast.

(G. W. Elsey.)—A tall, open-framed "Mission" clock facing southeast was found after the shock with its pendulum lodged on the top of a cross-bar of the frame. The position of the pendulum indicated a considerable increase in the amplitude of its vibration northeast-southwest in order to allow it to swing high enough to lodge. There were several similar cases of lodged pendulums in clocks facing in the same direction. Mr. E. Elsey also noted a water-tank spilt east and west, and trees swayed in the same direction. He heard a rumbling sound.

(H. Hintze.)—A water-tank spilt east and west. A hanging lamp swung in the same direction, dropping its chimney to the east. A bed on the porch rolled east and west. He heard a rumbling sound during the shock.

(Editor of the Daily Herald.)—Bed moved northwest-southeast.

(Farmers' and Merchants' Bank.)—The vault is built upon a foundation independent of the rest of the building. The front of the vault, facing southwest, is continuous with a lath and plaster partition which extends to the ceiling. On the left is a wash-room, and on the right an opening into the room at the side and back of the vault. The plaster partition is cracked where it joins the top of the vault and part way down the sides, probably indicating a greater amplitude of motion in the building than in the more solidly constructed vault.

(W. A. Harter.)—At Ceres, 6 miles south of Modesto, a tank spilt north-south.

(W. R. High.)—One mile north of Modesto, a tank spilt north and south during the early part of the shock, and east and west later. Trees swayed north-south.

(Empire Stables.)—Drop-lights swung and water in trough spilt northwest-southeast.

(A. L. Holtham.)—Milk pans on shelf supported by wires spilt milk west. The shock was preceded by a roaring sound.

(Modesto Gas Works.)—Water in the gasometer tanks spilt northwest-southeast. A chandelier in the building hung by a 0.375 inch gas-pipe 12 feet long; after the shock was over this chandelier was swinging northeast-southwest.

(J. T. McNeely.)—Station agent saw the railroad water-tank spill northwest-southeast.

(Editor of the News).—A water-tank belonging to J. Urie, 2.5 miles southwest of Modesto, was overthrown to the west.

The following were the clock records at Modesto:

Orientation.	Number of Clocks.	Stopt.	Not Stopt.
Facing northeast . .	4	3	1
Facing southeast . .	12	9	3
Facing southwest . .	7	5	2
Facing northwest . .	7	4	3
Total	30	21	9

Ceres, Stanislaus County. — The shock was felt, but is reported as not severe.

Oakdale, Stanislaus County (F. G. Keid). — The shock seemed to be in a northeast and southwest direction. In the school-house, a 2-story brick building, timbers lying in a northeast and southwest direction were loosened from the concrete at the ends, but those extending normal to this were not affected. Clocks stopt.

(E. C. Crawford.)—A flag-pole 110 feet high swayed apparently north and south; 2 clocks stopt; water in a tub moved north and south; and a stand lamp seemed to tip slightly north and south until steadied; but no objects were overturned.

Westley, Stanislaus County (W. G. Carey). — The town is on adobe soil with gravel at a depth of 20 feet. Furniture and pianos were moved across floors from the walls toward the south, and quite a number of pieces of furniture were toppled over. No chimneys were damaged, but several large water-tanks were demolished. These demolished water-tanks thru the country seem to have been rotated about one-fifth counter-clockwise. Cars on the track were moved at least a foot. At the railway depot, a 1,400-pound iron wheel was rolled back and forth for a distance of 9 feet northwest and southeast. There were 2 maxima in the movement of the earth, and the second was the stronger. Some men sleeping on a scow on the river 2 miles east of Westley heard a rumbling sound before any shock was felt, and came out of the scow to see what it was. Then the shock came and the waters rolled and foamed.

COAST RANGES EAST OF THE RIFT AND SOUTH OF MOUNT HAMILTON, AND THE WEST SIDE OF THE SAN JOAQUIN VALLEY FROM WESTLEY TO DUDLEY.

In the coast ranges on the east side of the Rift, south of Mount Hamilton, and along the west side of the San Joaquin Valley, settlements are few and widely scattered, so that opportunities for obtaining data as to the distribution of intensity were correspondingly rare. This territory was examined by Mr. G. F. Zoffman, under the direction of Prof. J. C. Branner, and the results of his observations and of others are embodied in the following report:

Pacheco Pass Road. — Starting from Hollister, the county seat of San Benito County, the writer went up the Pacheco Pass road over the Mount Hamilton range to Los Banos, in the San Joaquin Valley. There are but few brick or stone chimneys in this neighborhood, and inquiries were directed to the splashing of milk and the falling of dishes and other movable objects. At the entrance to the canyon thru which the road winds, several houses were visited. Only a few dishes had been broken and milk was thrown only from pans well filled. At Bell's Station no damage was done beyond the loss of milk. High bottles and dishes standing upon shelves were uninjured. The residents say that the vibrations were from east to west, and had a rocking motion. Before the shock a rumble was distinctly heard coming from the west.

At ranch-houses about 5 miles northwest of Bell's Station, and farther up in the mountains, the shock was of considerably less intensity.

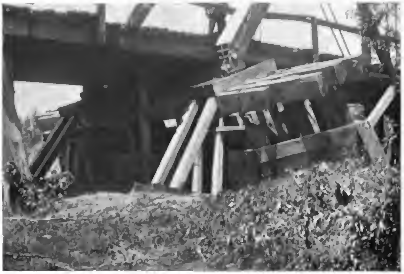
Mountain House. — The shock was reported as having been very mild; no dishes were thrown from shelves, nor milk splashed from pans. The proprietor states that the earthquake began with a north and south movement which later changed to the east and west. The shock here should be rated at V.

Going down into the valley on the east side of the Pacheco Pass the intensity of the shock perceptibly increased. At a ranch house 7 miles from the pass, nearly all the milk was thrown from pans and all the water from tanks. In a well where the water was 7 feet from the surface, some was thrown out. As noted by one gentleman, water was thrown from a tank, first from north to south, changing later to east and west.

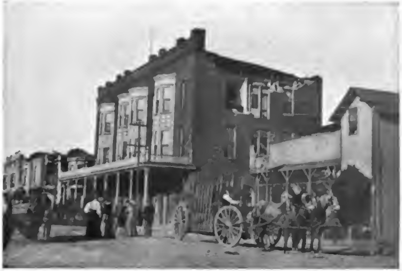
San Luis Ranch. — At the east end of the valley, on the San Luis Ranch, Mr. Mills stated that he distinctly felt the vibrations begin from north to south; there was then a lull of a few seconds and then followed a very noticeable east and west movement. The surface of the ground is said to have moved up and down like the waves of the ocean. Thruout this valley, which is made up of gravels deposited on firmer rocks beneath, the shock appears to have been nearly uniform.

Los Banos. — On emerging from mountainous districts into the deep alluvial plains of the San Joaquin Valley, the intensity of the shock increased, until at Los Banos it reached a maximum. A count of the chimneys showed 57 per cent (17 out of 30) fallen. All the brick chimneys were damaged, as shown by the accompanying photographs. (Plate 123B, C.) A peculiar feature of the effect upon these structures was that all the damage was on the northeast and southwest sides. Frame buildings were not damaged beyond the falling of plaster, or the throwing down of chimneys. According to the statements of the residents, and the data obtainable, the vibrations were north and south.

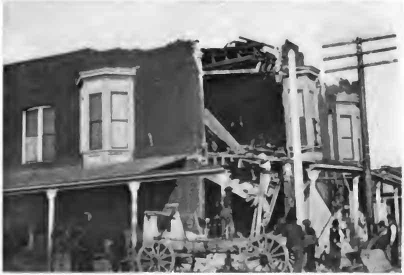
Volta. — Out of 7 chimneys 6 were thrown down by the shock. The plaster in frame houses was considerably damaged, but none of the buildings was thrown from its



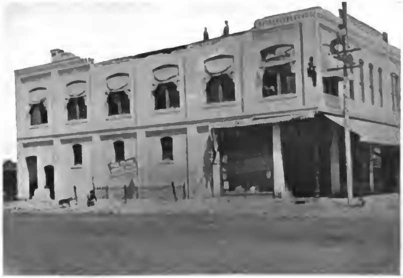
A. Bridge over Salinas River, 4 miles south of Salinas. South terminal pier thrust south 7 feet. A. C. L.



B. Los Banos Hotel. W. L.



C. Los Banos Bank. W. L.



D. Coalinga. Z.

foundations. The town had no brick structures. The water of the nearby irrigation canals had, in places, been thrown up on the banks as much as 6 feet above the usual level.

Newman. — From Los Banos toward Newman the intensity of the shock appears to have decreased. At the latter place, out of 8 brick buildings only one, just constructed, was thrown down; one was cracked, while the remaining 6 were undamaged beyond the falling of a little plaster. Sixty per cent (36 out of 60) of all the brick chimneys fell, altho little other damage was done to frame houses. A man who saw the 53,000-gallon railroad water-tank fall stated that at the beginning of the shock it began to sway north and south, changing later to east and west, and finally falling toward the west.

Crow's Landing. — Out of 18 chimneys only 3, or $16\frac{2}{3}$ per cent, fell. Considerable water was thrown from the tanks. At a brick oil-pumping station about 4 miles north of Crow's Landing a few cracks were made in the walls. The large oil-tanks and water-tanks were undamaged. People in this neighborhood state that the direction of the vibrations was first from north to south, changing later to east and west. Opinions differ on this point. Many also state that a circular motion was perceptible.

Grayson and Westley. — The town of Grayson is on the banks of the San Joaquin River. No damage was done by the earthquake. A very few things were thrown from the shelves, but no chimneys were thrown down. At Westley all the chimneys were found intact. One poorly braced railroad water-tank fell, and one remained standing. The people in this district maintain that the direction of greatest intensity was north and south.

From Westley to Mount Hamilton. — From Westley the writer traveled up the Arroyo del Puerto over into San Antonio and Santa Isabel Valleys and up to Mount Hamilton. There are but few houses on the east side of the summit, and but little data was collected. The best was obtained at the Phœnix Quicksilver Mine. Here there are several brick buildings and chimneys, but no damage at all was done to them by the earthquake. In the tunnel there was no shifting of strata. At Mount Hamilton Observatory a couple of chimneys were cracked, but none fell. From Mount Hamilton, the writer went to Paicenes, in San Benito County, thru the Panoche Valley to Mendota, thence to Coalinga, Dudley, Cholame, and Peachtree.

Paicenes. — Going from Hollister toward Paicenes the intensity of the earthquake rapidly decreased. At the latter place, which is on the gravels deposited by Tres Pinos Creek, none of the chimneys (3 in number) were damaged, nor were the clocks stopt. Water and milk were thrown from their receptacles in an east and west direction.

Elkhorn. — At the Elkhorn roadhouse there were 3 clocks; the one facing north was undisturbed, while the other 2, one facing south and the other east, stopt. No water was thrown from the troughs nor milk from the pans. A few miles northwest of Elkhorn, the milk was thrown from pans on the northwest and southeast sides. The information obtained from the residents in regard to the direction of the vibrations was very contradictory.

Emmet Post-office. — At Emmet milk was thrown out in small quantities, but no movable objects were moved or upset. Near the summit between Tres Pinos Creek and the Panoche Valley, the shock was so slight that people did not think of arising. Nothing was thrown over, nor was milk splasht from pans. From Paicenes, where the intensity may be rated at about VI, it gradually decreased up Tres Pinos Creek until at its source the intensity was about IV.

Panoche Valley. — This region lies on the east side of the Coast Ranges. At the head of the valley the shock was so slight that some of the inhabitants were not awakened. On going farther down into the lower ground where the soil is deeper, the intensity was slightly greater. At the Panoche store water was thrown from the tank, but no dishes were broken. After leaving Panoche Valley, no definite information was obtainable before arriving at the Chainey Ranch 14 miles west of Mendota. This ranch is on the plains on the west side of the San Joaquin Valley. The superintendent said that water was thrown out of troughs in a northeast and southwest direction. Movable objects were not disturbed.

Mendota. — Mendota is on the low alkali plains on the west side of the San Joaquin River in Fresno County. The intensity of the shock was comparatively light. In the town there were 17 brick chimneys and not one was thrown down. The railroad tank, two-thirds full of water at the time, was shaken down; but it was very insecurely built and only a very small vibration was necessary to overthrow it. Bottles and other unstable articles were not disturbed. The proprietor of one of the hotels, who was up, stated that the first movement was east and west, the second north and south, terminating with a decided twist. People who observed the plains at the time said that they assumed a wave-like appearance, and that trains rose and fell as the undulations past beneath the tracks. They also state that this wave motion was confined to the north and south movement, the east and west motion being more in the nature of a tremor. In the irrigated lands south of Mendota, considerable water was thrown from the canals.

Mendota to Coalinga. — At an oil-pumping station 10 miles south of Mendota, there were 10 large tanks; of these the roofs (unsubstantially braced) of 6 caved in, and much oil was thrown over the sides. The brickwork of the furnaces was not cracked. At the ranch-houses, about 6 miles east of the pumping plant, milk and water were thrown from their receptacles, and considerable damage was done by the breaking out of the head gates in the canals. The direction of greatest intensity is said to have been east and west. Many people in this region suffered from a nauseating sensation following the quake.

Coalinga. — The tops of a few of the walls of brick buildings were slightly damaged, as shown by the accompanying photograph. (Plate 123D.) A few dishes and bottles were thrown from the shelves, and water was slopt out of the tanks, but none capsized. The direction of greatest intensity of the vibrations was northeast-southwest. At the oil wells no damage was done either to wells or pipe lines. At a pumping station, the brick lining of the furnace was cracked slightly. Considerable oil was thrown from the tanks. In a large reservoir containing No. 10 oil (very heavy), the oil was thrown up 10 inches on the northeast and southwest sides. In a pump having No. 16 grade, the oil was splasht 3 feet up the sides.

Dudley. — Going south from Coalinga thru the Kettleman plains, the intensity of the shock apparently decreased, tho there were so few inhabitants that it was impossible to get definite data. At Dudley Station (a farm-house) nothing on the shelves was disturbed nor had milk or water slopt over. It was evident that the earthquake was less intense than at Coalinga. Entering the mountains west of Dudley, there was a further decrease in the intensity.

Cholame. — At the east side of the Cholame Valley, the occupants of a ranch-house had not felt the shock. At Cholame Post-office the shock was felt, but very slightly. The postmaster stated that it had a rocking sensation rather than a shaking one. At the Cholame ranch a mud chimney about 7 feet high was left standing out by itself, unharmed, but very insecure.

Parkfield. — Near Parkfield there are fissures in the earth, bearing N. 45° W., known to have existed since the first coming of white men. In some places the depressions are 35 feet deep. These fissures were not reopened at the time of the late earthquake.

Stone Canyon Coal Mine. — At the coal mine the shock was very noticeable. The fireman on duty the morning of the earthquake stated that the smoke-stacks, 35 feet high and guyed, swung considerably in various directions. No shifting occurred in the strata of the underground workings. It was stated that the movement was northeast and southwest.

Peachtree. — As Peachtree was approached, there was a perceptible rise in the intensity. About 2 miles east of the post-office, dishes had been thrown over and milk spilt from pans. At the station itself, however, nothing had been overturned. The region visited between Cholame and Peachtree is in small valleys lying in the mountains on the west side of the Salinas Valley. The soil is nowhere deep.

Cantua Creek, Fresno County (S. C. Lillis). — The shock was severely felt in this region, and its direction was southeast-northwest. A series of landslides caused by the earthquake were reported by Mr. Lillis, extending from the northwest corner of T. 18, R. 14 E., M.D.M. to the middle part of T. 15, R. 11 E., a distance of about 23 miles. The features were not at first recognized by Mr. Lillis as landslides, and as they occurred on the east side of the Coast Ranges, on the border of a portion of the San Joaquin Valley, where the intensity was abnormally high, the hypothesis was entertained that there might have been a supplementary fault in that region along the edge of the mountain range. The remarkable alinement of the features lent support to this suggestion. The region was, however, subsequently visited by Prof. G. D. Louderback, in company with Mr. Lillis, and the features reported by the latter were found to be landslides. Professor Louderback furnishes the following note regarding them:

> The phenomena reported by Mr. Lillis are several landslides. In each case the effect of the movement can be followed in detail and sharply delimited. The form of the moved body is typically that of the landslide in each case, with the cliff at the upper end curved and concave toward the lower part of the slope. The mass has moved away and downward, leaving in some instances an open space or fissure, partially filled at the present time (May, 1907) by caving. The back cliffs, followed around, gradually pass into lateral planes of movement, which themselves are sometimes gaping on the more elevated side, showing a forward and slightly lateral movement of the mass. (See plate 125B.)
>
> No general fissure, fault, or rift was observed passing thru or near these landslides, altho a careful search was made for such features. I suspected at first that there might be such a rift-line, because the landslides are approximately along one line or belt. This appears, however, to be due to the fact that one particular formation is especially favorable to landsliding, all the slides that I saw along the lower part of the range being associated with a thick reddish-brown shale of a definite stratigraphic horizon (Tejon ?). The general structure of the range causes the rocks of any given horizon to outcrop along a line roughly parallel to the range front (approximately northwest-southeast). The landslides all lookt fresh, and according to Mr. Lillis several of them (and probably all of those under consideration) were caused on April 18, 1906. I made a trip across the hills from the valley to New Idria and noted nothing that appeared to be a recent seismic line.

EAST SIDE OF THE SAN JOAQUIN VALLEY SOUTH OF MODESTO AND THE ADJACENT PORTIONS OF THE SIERRA NEVADA.

In this region information regarding the intensity of the shock is rather scant. The shock was in general not sufficiently severe to excite alarm, and people as a rule did not note carefully its effects at the time. Such records as are available indicate that an intensity ranging from VI to V prevailed to the eastern edge of the valley, but that it died out rapidly in the mountains beyond.

Merced, Merced County. — Clocks generally were stopt, and hanging objects were caused to swing. One chandelier was observed to swing north and south, and then in a circle.

Madera, Madera County (F. E. Smith). — The principal disturbance was preceded by a tremulous motion for about 10 seconds. There were 2 maxima in the principal disturbance, the second being the stronger; and a tremulous movement succeeded it. The apparent direction of the movement was from southeast to northwest, and objects were overturned toward the northwest. The duration of the shock was thought to be 2 minutes. It was severe enough to rattle windows and move doors; to cause the bed to move; to swing hanging objects and stop clocks; and to overthrow ornaments, vases, etc., but not to throw chimneys. In other parts of Madera County the shock was reported from Daulton, Magnet, and Gold, but without sufficient details to afford a clear idea of the intensity of the shock.

Fresno, Fresno County (A. C. Olney). — No. VI of the Rossi-Forel scale describes conditions here quite accurately. There was a general awakening of sleepers, oscillation of chandeliers, stopping of clocks, and considerable agitation of trees. Some people ran out of their houses. Water in troughs was spilt out, etc. No damage was done to buildings.

(J. P. Bolton, observer of the U. S. Weather Bureau.)—At the time of the earthquake Mr. Bolton was on the third floor, standing near a window. The time of the shock was $5^h\ 13^m\ 30^s$. The first shock lasted about 10 seconds. It stopt clocks, swayed buildings, gasoliers, furniture, unlocked doors, window-weights and shutters. There was a short interval of cessation, then a second shock which lasted about 30 seconds, but was less severe than the first. It had a tremulous motion which gradually died away. Each shock developed its greatest intensity near its beginning. The apparent direction was from south to north. The intensity of the first shock was sufficient to sway the stoutest building and disturb its contents without displacing them, and to damage walls slightly. The only sound observed was that caused by the jarring of the building, etc. Many dogs barked vigorously shortly before the first shock.

Reedley, Fresno County (John Fairwether). — The shock was north and south; clocks stopt; some plaster was cracked, but no chimneys fell; a front door which was locked was caused to swing open. At Conejo water was slopt out of ditches to the north for 40 feet. At Jameson 2 distinct shocks were felt. At Riverdale, hanging objects were caused to swing. At Kingsbury, a slight shock was felt. At Fowler 3 wells were filled with sand. At Sanger a clock was stopt.

Visalia, Tulare County (F. A. Swanger). — A rocking-chair rocked vigorously northeast and southwest, but no shifting of the chair was observed as it rocked. The swell and fall of the earth-wave seemed strong.

(A. M. Doty.)—Four shocks were felt in Visalia, the last being the most pronounced. The town clock and almost all pendulum clocks in the city stopt. The vibration was from north to south. The Delta Building, a two-story brick structure, swayed to the south so perceptibly that it seemed difficult for it to regain its equilibrium. When it did sway back, the tin roof rattled as if some one were pounding on it with a hammer. Practically everybody in Visalia was aroused from sleep by the quake.

Dinuba, Tulare County (Miss L. H. Tindall). — There was a smart shock. A clock at the bank stopt. A crack in a brick building was so enlarged that the wall had to be strengthened by rods. A chandelier swayed from south of southwest to north of northeast. Elsewhere in Tulare County shocks were reported at Exter, Kaweah, Orosi, Porterville, and Tulare.

Bakersfield, Kern County (A. G. Grant).—The shock was strong enough to rattle windows and doors. Oil slopt out of tanks in the oil-fields 5 miles to the northeast of the city. Some clocks are reported to have stopt.

Isabella, Kern County (Stephen Barton). — Mr. E. King, lying in bed, noticed the swinging of a pistol scabbard suspended by a strap directly over his head.

EAST OF THE SIERRA NEVADA.

DATA COLLECTED BY GEO. D. LOUDERBACK.

General note.—In the towns along the east base of the Sierra Nevada and within 25 or 30 miles of the base, the shock was distinctly felt, movable objects were seen to swing and heard to bump or rattle, and a very small number of persons were awakened. Farther east the most notable feature of the reports is that wherever the effects of the earthquake were made evident, the physical signs, such as the swinging of suspended objects, etc., were described almost to the exclusion of direct physiological effects. This is apparently at variance with the principles upon which the Rossi-Forel scale is founded, as the first 3 grades of intensity, beginning with the lowest, are based on feeling; the visible disturbance of objects not beginning until grade IV is reached. This may be due entirely or chiefly to the following conditions: Settlements are few and far between and many contain a very small number of inhabitants. When the earthquake occurred, the great majority were asleep, and the few who were up were moving about at active work and were in general not of a sensitive type. It is therefore probably impossible to get satisfactory and correct statistics indicating the distribution of the zones of intensity of the first 3 grades; and the sensible effects of the earthquake probably extended much farther east than reported.

Perhaps the most important of the physical signs reported is the disturbance of smooth water surfaces. In five instances, at three different localities, ditch tenders or irrigators noticed an agitation of quiet water surfaces and that the water lightly splasht against the sides as if from low waves, or as in a vessel of water when it is slightly tilted. As the morning was clear and entirely without wind, it imprest them as peculiar, and the matter was reported when they went to breakfast. The suggestion of one that something peculiar had happened, and of another that it was an earthquake, was each in its place the incitement of sallies of wit at the expense of the reporters. When news of the California earthquake reached these places several hours afterward, the time was found to agree as closely as determinable with the phenomena of the morning. In each of these cases, however, it was reported that no shock was felt. It is suggested that with moderately long waves such surfaces may prove very sensitive indicators of intensities down to the lowest degree on the scale.

The farthest point east at which earthquake effects were reported was Winnemucca, about 340 miles from the fault. A careful search was made for persons who had felt or seen indications of the shock. Only one apparently authentic case was found, and that was of a nurse who had retired a little after 5 o'clock, after a night's work at the County Hospital. She was lying quietly in bed and felt no disturbance whatever; but noticed a hanging lamp swing gently back and forth. Careful inquiry at newspaper offices, the telephone office, the post-office, and of the railroad agent, the weather bureau observer, and many individuals in different parts of the town, failed to discover another observation. This is rather remarkable, because Winnemucca is a town of considerably over 1,000 inhabitants. It is believed that the one definite report obtained is correct; and, as corroborative testimony, may be added the reports from two other localities almost as far east as Winnemucca, in which similar phenomena were described (in one the disturbance of a water surface, in the other a swinging lamp), with the further similarity that no shock was felt.

The elongation of the intensity zones in a northwest-southeast direction is marked. The strongest effects east of the Sierra Nevada were felt with practically the same intensity from at least Sierra Valley to Lone Pine (about 250 miles along the range), while 50 miles east of the Sierra the intensity had materially lessened, and 100 miles east reports are practically unobtainable. This agrees, of course, with the elongation of the locus of disturbance.

It also appears probable that the sensible effects extended farther along Humboldt Valley, which is practically parallel to the direction of propagation, than along those lines where successive mountain ranges were thrown across the advancing waves, as in the southern Nevada region.

In most cases the direction of vibration was given as north-south, or northwest-southeast; tho in two or three cases north of west to south of east, or east-west, directions were given. Most of the clocks reported stopt faced north or south; a few faced west.

In a few cases the statement was made that there were two shocks very close together, but most of the observers did not distinguish more than one.

Details for the various localities follow:

Round Hole, 70 miles north of Reno (F. McMillan). — A distinct earthquake was felt which lasted several seconds.

Peavine Mountain. — A number of ranchers and miners were up at the time of the earthquake, on the north side of Peavine, about 10 or 12 miles northwest of Reno. No one noticed the shock nor any indications of it.

Reno. — The shock was distinctly felt by a number of persons. Some were awakened. The great majority knew nothing of it. A good account was given by Mr. Jensen, of the U. S. Weather Bureau. He was in the office to take instrumental readings. The office is on the fourth floor of a rectangular brick building, longer east-west than north-south. He heard some pictures rattle and thought the janitor was getting remarkably industrious downstairs; then he noticed that they were all rattling and surmised that it was an earthquake. His attention was attracted to an electric bulb on a long wire hanging from the ceiling, only a few inches from the west wall. It was swinging so as to hit a metal nipple on a pipe in the wall, thus making quite a noise. The building seemed to shake east-west.

Olinghouse. — Many were interviewed, but none had felt the shock. While there are one or two vague reports, it is probable that no one really felt the effects at this place.

Wadsworth. — A canvass failed to elicit any definite account. The postmaster claimed he talked with many people, but knew of none who had observed the shock.

Hazen. — Quite a number of people were interviewed, but no good definite account could be obtained. Most people decidedly had not felt it, and were not sure of any one who had. There were one or two hazy reports of persons who were supposed to have felt or observed it, and one man admitted having noticed a "light shock."

Virginia City. — Only a few persons noticed the shock. Mr. D. T. Smith was sleeping on the third floor of a rectangular building that stands east and west. He woke up and felt a movement of the building. An electric globe suspended by a cord from the ceiling (about 5 feet) swayed about 1.5 inches with an elliptical movement, the major axis a little north of west. No one else in the building noticed it.

Wabuska. — A few are reported as feeling a "jar." No one noticed the direction.

Yerington. — A few felt the shock. It was light and described as north-south. One person in bed but awake said the bed rocked and a curtain swayed north-south, producing a sort of dizzy sensation.

Fallon. — Three persons were found who claim to have been awakened; they were all women and light sleepers. One (Mrs. E. W. Black) awoke and heard a noise which she thought was the rattling of the window weights. Another (Mrs. I. H. Kent) awoke hearing a noise like the rattling of a window. She also noticed a bird cage and a hanging plant swing in a north-south direction, the distance from the point of suspension to the center of gravity of these being about 5 feet. Others in the same houses noticed nothing.

It is reported that ditch tenders on the Government irrigation canal noticed a disturbance of the water surface, and light splashing of the water as if by low waves or rocking. They reported it at camp in the morning some hours before news of the California earthquake arrived. Direct testimony is lacking on this point, tho the report was generally believed at the Reclamation Service Offices at Fallon and Hazen.

Fairview. — Reports from several sources are to the effect that no shock was felt, and no distinct evidence of the earthquake was observed.

Lovelock. — Several clocks are said to have stopt, but some of the reports, tho direct, seem to be unreliable. Several persons were awakened. One (Mr. Dawkins, principal of the Lovelock School) felt a slight shaking; others heard a noise as if a person were knocking, or the blinds or ventilators had rattled. One feared the powder house had "gone up." (F. J. Gunnell, A. G. Bosk, C. H. Valentine.) The clock in the hotel is said to have stopt. It hangs on an east-west wall and faces south. The station clock, in a similar position, was also reported stopt. On several ranches 8 to 12 miles south of Lovelock the irrigators noticed waves or splashing in ditches or canals, and reported the same at breakfast that morning. Ditches extend north-south; the slope is very low, almost horizontal, and the water surface smooth and quiet. (John Sullivan, irrigator for Lovelock Commercial Co.; Peter Naker, rancher; James Jensen, son of rancher, etc.) One report speaks of a lamp swinging. Those who saw the effects on water surfaces, and others in general, felt no shock.

Mill City. — The station agent said he had no positive indications of the earthquake and no one felt it.

Unionville. — Tom Powell, a rancher 4 miles south of Unionville, says that his wife woke him about daylight, and called his attention to the lamp swinging. They felt no shaking. They noticed later that a fine dust from the adobe walls had crumbled down on to the surface of the cream.

Winnemucca. — A rather thoro canvass of the town was made because it is the farthest east at which any report of the earthquake was made. Only one definite account was obtained, and it is believed to be reliable. Mrs. Sloane, nurse at the County Hospital, had been on night duty and had just retired. As she lay quietly in bed, she noticed a hanging lamp with pendant glass prisms swing. It swayed, in her judgment, nearly 3 inches, not far from east and west. She called her husband's attention to it and suggested that it might be due to an earthquake. It continued swinging some time. No shock was felt, nor was swaying of the building noticed. The railroad agent, the weather bureau observer, who was up at the time, the postmaster, the employés in the telephone office, the people in both of the newspaper offices, and a number of other people in various parts of town, all said that they had felt no shock and had seen no effects of it, and knew of no one who had, except a few who had heard of the case of Mrs. Sloane. Another person, reported by one or two as having felt the shock, was interviewed, but claimed that she had felt no shock and that the report must have been started as a joke.

Hawthorne. — Two clocks are said to have stopt. Mrs. Taylor described the shock as a tremor, as if a pet dog were scratching and passing the bed, followed by a distinct movement toward the north and back toward the south. Mr. Brodigan, in the second story of the court-house, felt quite a shake.

Mina. — The shock was distinctly felt by some. In the store it was said that the building distinctly swayed, the dishes and tinware on the shelves making some slight rattling. In the telegraph office the clock stopt. The shock was very slight, and felt by only a few.

Bodie (E. B. Brooks). — The shock was perceptible; some clocks stopt. It was noticed by occupants in some 2-story buildings, but was not generally felt.

Mono Lake. — A slight shock was felt on the west side of the lake.

Candelaria (Charles N. Platt, weather observer). — He did not feel the shock and knew nothing about it until the newspaper report came.

Laws. — Ten or more persons noticed the shock, which was slight. W. M. Richards stated that there were 2 shocks, one almost immediately after the other. The first was a gentle rocking motion, the second small jerks. The total duration was about half a minute.

Tonopah. — Several communications were to the effect that no one had noticed any indications of the earthquake.

Goldfield. — Several reports were received to the effect that no shock was noticed. A report was in circulation that the springs had changed somewhat in their flow, but the Superintendent of the Western Reclamation Company (F. A. Thompson), who keeps a very close watch of the wells and springs, says there was no change at all in the flow nor any other indication of an earthquake.

Eureka (Clay Simms). — A slight shock was felt, the movement being from west to east. It seemed to last for about a second. It made hanging objects swing, but did not stop clocks.

Bishop (W. A. Chalfant). — The shock was strong enough to waken many persons asleep. Large clocks in the jewelers' stores were stopt. The length of the vibration was unusual, but was not timed. The earthquake was not felt as a sharp shock, but rather as a long and not severe rolling motion. Doors, windows, window weights, etc., were shaken, and hanging objects, such as incandescent bulbs, swayed back and forth thru an arc of 12 to 18 inches, double amplitude. No damage whatever was done to property. Doors on the north and south sides of buildings seemed to have been affected most. In one instance a box of dry goods was moved about 3 inches. Out-of-doors the rumble of the shock was noted by a few persons.

Independence (Mrs. E. M. Brooks). — Some clocks were stopt and windows rattled, but few felt any shock.

Lone Pine. — A number of clocks were stopt, all facing north or south. The shock was noticed by only a few persons. According to one description, there were 2 shocks a few seconds apart. It seemed like a rolling movement, and a hanging lamp was noticed swinging north-south. Trees shook.

Keeler. — Only 2 or 3 persons noticed the shock. It was only slightly perceptible.

In gathering information concerning the California earthquake of the morning of April 18, as felt in the Western Nevada region, two other closely succeeding shocks were brought to light, one of which had much stronger local effects than the greater but more distinct earthquake.

The Earthquake of April 19, 1906, *about* 2^h 5^m P. M.:

This shock was mentioned by so few persons that I was at first inclined to consider it imaginary. It was reported, however, by reliable persons not known to each other in three different towns. The most definite accounts are as follows:

Reno (Miss Lewers). — Observer on the third floor of the Agricultural Building at the University, in the photographic laboratory; felt a very distinct shock, but did not remember the direction of movement.

Olinghouse (Miss Norris). — The person reporting and her sister were sitting in the house and felt a distinct shock. Fearing it was the forerunner of a larger earthquake, they ran outside.

Hazen. — A shock not generally felt was noted distinctly by Mrs. MacGregor, at the Reclamation Service headquarters.

The Earthquake of April 19, 1906, 8^h 15^m to 8^h 30^m P.M. (Intensity, IV–V.) — This earthquake was distinctly felt along the east slope of the Virginia range and the valley land directly east and not far north or south of Lat. 39° 31′. Wherever reported it was much stronger than the shake produced by the California earthquake of the previous day. It was generally felt at Hazen, Wadsworth, Olinghouse, and neighboring places where it is hard to find any one that noticed any effects of the great quake. In Hazen it rattled windows, made gas jets and lamps swing, and doors swing on hinges. The railroad station clock is said to have stopt. At Wadsworth, it made the windows rattle and caused some fear, owing to reports of the San Francisco disaster. One person describes it as a quick sharp shock like a blast. At Olinghouse also it was felt as a sharp shock — one called it a quiver — and caused windows to rattle. It was felt as far east as Brown's Station. It was apparently not felt at Fallon, tho it was distinctly felt 12 miles west at Carson Dam. In the Reclamation Service camp at Fernley it was quite strong, as felt on the ground in the tent. Judging from its areal distribution, it is suggested that this earthquake is related to the fault along the east base of the Virginia Range. The rough time estimates vary from 8 to 9 o'clock, but in cases where the time was noted more particularly, the variation is between 8^h 15^m and 8^h 30^m. The vibration was apparently northwest-southeast, or north-south, at Hazen. At Fernley (a short distance south of Wadsworth) it was described as northeast-southwest.

OBSERVATIONS OF J. A. REID.

Professor J. A. Reid, who has been engaged for some time past in a geological study of the fault-zone of the eastern flank of the Sierra Nevada, made an examination of various faults with which he was familiar, with the view of ascertaining whether or not evidence could be found of movement at the time of the earthquake. No such evidence was, however, found. He also made an examination of several hot springs along the base of the mountains, to ascertain what changes, if any, had been caused by the shock. The only ones which seem to have been affected are the Steamboat Springs, 12 miles south of Reno.

In addition to making these examinations, Professor Reid obtained some valuable information regarding the intensity of the shock, as given in his notes which follow:

At Reno people were not generally awakened. There were no exact records of the time, direction, or intensity of the shock. The movement was large, but slow, and of long duration — probably about 40 seconds in total. The clock of ex-meteorological observer S. B. Doten stopt. An extension incandescent electric light, on an 8-foot cord, so arranged that it could swing only north-south, was set swinging thru a 3-foot arc. This was on the first floor of an old wooden house, and gives some indication of the magnitude of motion and time of oscillation. Mr. Doten was awakened by the shock and counted 20 seconds of lesser motion after he was fully conscious. No noise was heard. Another observer was awakened, and saw a 4-foot light and cord swing about 18 inches nearly east-northeast and west-southwest. At the University of Nevada similar lights were set swinging with a large east-west component of motion.

At Steamboat Springs the shock was felt as a long, gentle swing. A second shock, seemingly as hard as the first, was felt the second or third night after. At the Rocky Hill Mine, in the foot-hills of the Virginia Range, midway between Steamboat Springs and Washoe, the shock was not felt by men at work, and loose rock in the main tunnel was not dislodged.

At other points between Steamboat Springs and Carson, as at Lakeview, Washoe, and Lewer's Ranch, the earthquake was felt as a long, gentle swing. At Bowers Mansion, a few feet from the steep granite escarpment of the Sierra Nevada, all sleepers were awakened by the shock, which appeared to have greater intensity near the harder, more elastic rocks than in the loose valley deposits. The same result occurred in Carson Valley, south of Carson. At and near Genoa, directly at the base of the 4,000-foot scarp of the Sierra, the shock generally awoke sleepers, and trees were noticed to swing as in a wind. A few miles eastward, however, in the river-laid valley deposits, the shock was felt by very few persons.

In the town of Gardnerville, some few miles east of Genoa, a number of people complained of a feeling of nausea while eating breakfast at the time of the earthquake, but felt no motion. In all cases the shock felt was characterized by long, gentle motion; in no cases was sharp movement experienced.

At Virginia City, about 6 miles east of the Rocky Hill mine, the shock was felt by very few people, and they were in the tops of the higher buildings. Around Dayton and nearby towns no reports came of persons feeling the earthquake. The Virginia Range seems not to have been greatly shaken. At Carson, the most reliable and abundant data were obtained. Mr. C. W. Friend, the well-known meteorological observer, obtained a seismograph record of the shock,[1] which was by far the heaviest ever recorded by him, the stylus of the instrument swinging entirely off the plate. Yet the motion was so gentle and of such a long period that sleepers were not generally awakened. The time of oscillation was not determined, but was described as being like the swinging of a hammock. The seismograph record is peculiar in that the stylus appears nearly to have retraced its course over one large curve. Carson lies about 3 miles east of the steep rise of the Sierra Nevada, with a deep deposit of river wash between. At the southwest, however, a low hill of schistose rocks just enters the town limits. This structure may play a considerable part in the peculiar motion of the earth here in this and other earthquakes.

At Paradise Valley, north of Winnemucca, the earthquake was felt by the few people awake or moving at that early hour. A rancher who happened to be near a small pond noticed an unusual agitation of the water, and supposed an earthquake to be the cause. The time was subsequently found to correspond with that of the shock, as reported elsewhere. No motion was felt, however.

EXPERIMENTS WITH A SHAKING MACHINE.

By F. J. Rogers.

The investigation described below was undertaken with the hope of offering some explanation, based directly on experiment, of the greater destructiveness of earthquakes in regions where the foundations of structures are supported by more or less soft ground than where these foundations are based on solid rock.

As an earthquake consists in the actual shaking of the earth's crust it would seem, upon first thought, that the more rigid the foundation the more destructive would be the effects of the earthquake upon the structures so supported. This is in general not true, however.

In conversation with Dr. Branner, the great desirability of some experiments on this subject was suggested to the writer. In the first experiment which promised any interesting results a bucket of molding sand was poured out upon a board about 20 × 30 inches. The board was shaken in a horizontal direction through an amplitude of 2 or 3 centimeters, by means of a small motor. When the sand was moderately wet, the amplitude of vibration of the top of the mound was greater than the amplitude of vibration of the board on which the sand rested. This result is contrary to what I should have expected. When the result of this preliminary experiment was reported to Dr. Branner some time afterwards, he was greatly interested and urged the writer to carry on a series of similar experiments on a larger scale, the same to form a part of the report of the Earthquake Investigation Commission. As a result the apparatus described below was designed and was later constructed by the Mechanical Engineering Department of Stanford University.

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[1] This seismogram is referred to in another part of the report.

In designing a shaking apparatus to imitate an earthquake, certain conflicting conditions must be taken into consideration. It would seem that the apparatus ought to be on as large a scale as possible, but if it is on a large scale, it must needs be very expensive. If the linear dimensions are increased in any ratio, say trebled, the volume, weight, strength, and power to operate must be increased in the *cube* of this ratio; hence if the linear dimensions are trebled, these quantities must be increased 27-fold. Moreover, it is obviously impossible, at any cost, even to approach the scale on which nature acts. With these considerations in view it was decided that the scale of the apparatus should be as small as is consistent with obtaining results from which general conclusions might be drawn.

Earthquake motions are exceedingly complex, but it was not thought worth while to imitate this complexity, but rather to confine the shaking motion to a simple to-and-fro horizontal motion in one direction.

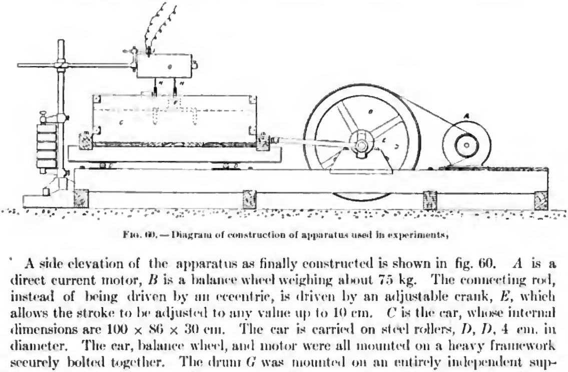

FIG. 60.—Diagram of construction of apparatus used in experiments.

A side elevation of the apparatus as finally constructed is shown in fig. 60. *A* is a direct current motor, *B* is a balance wheel weighing about 75 kg. The connecting rod, instead of being driven by an eccentric, is driven by an adjustable crank, *E*, which allows the stroke to be adjusted to any value up to 10 cm. *C* is the car, whose internal dimensions are 100 × 86 × 30 cm. The car is carried on steel rollers, *D*, *D*, 4 cm. in diameter. The car, balance wheel, and motor were all mounted on a heavy framework securely bolted together. The drum *G* was mounted on an entirely independent support. A paper wrapt around the drum received traces representing, (1) the motion of the car, (2) the motion of a block *F* set in the material on the car, and (3) the beats of an electromagnet *I*, electrically connected to a seconds pendulum. (The pencil actuated by the electromagnet was on the same side of the drum as the other tracing pencils, instead of being on the opposite side, as shown in the figure.) The block *F* was 30 cm. square and was furnished with side pieces running 6 cm. down into the sand, so that its motion was necessarily the same as the material immediately under and surrounding it.

The experiment consisted in loading the car and then shaking it by means of the motor, with various amplitudes and frequencies. While the car was being shaken, the drum was rotated by hand, and the relative motion of the car and the block embedded in the load was determined by measuring the traces on the paper wrapt around the drum.

The material with which the car was loaded was limited almost exclusively to ordinary building sand from a creek bed, combined with various amounts of water. Some experiments were made with gravel, but lack of time and the necessity of completing the work for publication in the report of the Earthquake Investigation Commission prevented more extensive experiments.

When the car was loaded with moderately dry sand containing 10 per cent of its weight of water or less, it was plain to direct observation that the sand was moving almost perfectly with the car, so long as the frequency was less than 2½ double vibrations per second. However, if the sand was wet locally by pouring water upon it, it was also very evident that the wet sand did not move at the same rate as the nearby dry sand. In the first place, the amplitude of vibration of the wet sand was greater than that of the dry sand; and in the second place, the reversal of motion was much quicker in the case of the former than of the latter. In the region between the wet and the dry sand, the difference in the relative motions of the two, causes the surface to be broken up by crevasses which open and close periodically. This breaking up of the surface is quite irregular, varying from moment to moment.

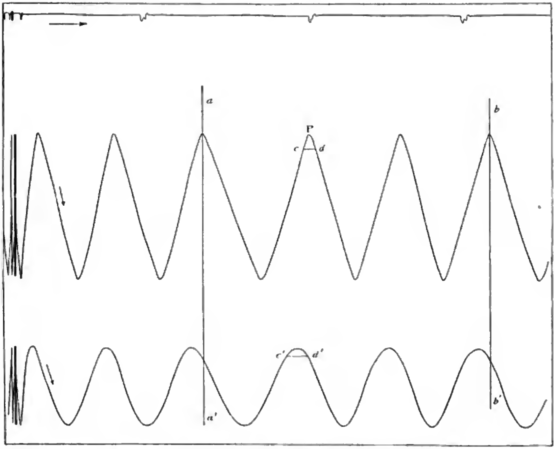

FIG. 61.—Curves obtained on recording drum. Reduced about half.

For a precise determination of the relative motion of the car and the sand with which it is loaded, it is necessary to measure the curves traced on the revolving drum described above. The method of doing this will be best illustrated by taking a particular case. Fig. 61 is a copy of one of the curves obtained on the drum. The lower sinuous curve is the trace made by the pencil attached to the car; the middle zigzag line is the trace made by the pencil attached to the block embedded in the sand; the upper line is the trace of the electromagnet beating seconds. In this particular case the sand contained all the water that it would hold, so that it was very soft, almost semi-fluid. The amount of water was determined by weighing a portion of the wet sand and then weighing it again after it had been thoroly dried. In this case the material contained 20 per cent of water to 80 per cent of sand.

The traces show at a glance that the amplitude of the motion of the sand was much greater than that of the box. By reference to the transverse lines *aa′* and *bb′*, it is obvious that the motion of the sand lags behind the motion of the box — in this case about one-sixth of a complete period. Finally, the difference in the character of the two motions is shown by the sine curve in one case, and the zigzag line in the other case. The sine curve shows that the car has a simple harmonic or pendulum motion, as must necessarily be the case on account of the way in which it is shaken. On the contrary, the block embedded in the sand moves with an approximately uniform velocity until the end of the "stroke," when its motion is very quickly reversed; after which it again moves with uniform velocity until its motion is again quickly reversed. The acceleration at the instant the motion is reversed is a proper measure of the quickness of reversal. This acceleration can not be measured, but the average acceleration during a short interval of time while the motion is being reversed can be determined. If *cd* and *c′d′* (see fig. 6) are drawn at corresponding parts of the curves, then the lengths of these lines are proportional to the times required for corresponding changes in the two motions. The square of the ratio of these two times, divided into the ratio of the two amplitudes, gives the ratio of the two accelerations during the motion *cPd*. The closer *cd* is taken to *P* the greater this ratio becomes. In the present case, in which *cd* is drawn at one-tenth of the amplitude from *P*, the ratio of the two accelerations is about 3. As moving forces are always proportional to accelerations, the bearing of this result on the destructiveness of earthquakes is evident.

The data obtained from fig. 61 may be presented as follows: Load shaken, sand 80, water 20. Depth of sand, 22 centimeters. Frequency of motion, 1.7 double vibrations per second. Amplitude of car, 4.5 centimeters. Amplitude of block in sand 8.5 centimeters. Lag of block, one-sixth period. Ratio of accelerations at reversal, 3 or greater.

A large number of experiments were made with a load of wet sand having the above composition. Results similar to the above were obtained whenever the frequency of the motion was rather small. However, when the frequency of the motion was considerably increased, or when the ratio of water to sand was changed, the results obtained were quite different. In general the less water the sand contains the more nearly does it move with the car. The accompanying tables contain results from a large number of experiments in which the composition of the load and the frequency of motion was varied.

The data from these tables are plotted in figs. 62 and 63. In all cases the number of complete or double vibrations per second is plotted along the x-axis, while the amplitude of motion of the block embedded in the sand is plotted along the y-axis. The points representing observations do not fall upon smooth curves, but this is hardly to be expected from the nature of the experiment.

The data as illustrated by the plots show that when the load consists of sand and water in the ratio 4 to 1, for low frequencies, the sand oscillates through a much greater amplitude than the car, and that the amplitude rapidly decreases as the frequency increases and becomes quite small for frequencies of 3 or 4 per second. On the contrary, when the load contains only 15 per cent of water, it moves with the car, for low frequencies, and the amplitude increases with the frequency. The results actually obtained are subject to a large probable error, but there can be no doubt about the decreasing amplitude with increasing frequency in one case and the opposite result in the other case. When the sand contains about 15 per cent of water, it seems to be more adhesive and more capable of packing into a relatively compact mass. In this respect it is distinguished

Results of experiments in which composition of load and frequency of motion was varied.

WATER: SAND = 20:80			WATER: SAND = 17:83			WATER: SAND = 15:85		
Frequency	Amplitude in Centimeters		Frequency	Amplitude in Centimeters		Frequency	Amplitude in Centimeters	
	Car	Block		Car	Block		Car	Block
.5	6.1	9.5	.6	6.0	7.9	.9	6.1	6.3
.75	6.1	9.7	1.0	6.0	8.5	1.7	6.2	7.4
1.0	6.1	9.5	1.4	6.0	9.0	2.6	6.4	8.1
1.3	6.1	9.2	1.6	6.1	9.3	3.3	6.5	8.4
1.5	6.1	7.3	2.3	6.1	9.5	3.6	6.3	8.0
2.0	6.2	5.9	2.4	6.1	7.5	1.0	3.2	3.4
3.2	6.3	1.9	2.8	6.1	8.0	1.2	3.3	3.8
3.5	6.4	.3	3.6	6.4	4.4	1.8	3.3	4.4
.83	4.3	7.4	3.8	6.4	4.3	2.7	3.4	4.7
1.0	4.3	7.2	.85	3.3	5.2	3.2	3.4	5.1
1.3	4.3	6.5	1.5	3.3	5.3	3.9	3.4	5.2
2.1	4.3	3.5	2.5	3.3	5.4	4.0	3.4	5.0
3.0	4.3	2.4	3.1	3.4	4.3	4.6	3.6	5.5
4.0	4.5	1.2	4.1	3.5	2.2			

WATER: SAND = 12:88.			WATER: SAND = 10:90 } Two WATER: SAND = 20:80 } layers			DRY GRAVEL.			WET GRAVEL.		
Frequency	Amplitude in Centimeters		Frequency	Amplitude in Centimeters		Frequency	Amplitude in Centimeters		Frequency	Amplitude in Centimeters	
	Car	Block		Car	Block		Car	Block		Car	Block
1.8	6.2	6.3	1.4	4.4	4.5	2.5	4.6	4.6	1.9	4.6	4.6
2.5	6.4	6.4	2.0	4.7	6.3	2.8	4.6	4.9	2.7	4.8	4.9
2.8	6.2	6.4	2.3	4.7	6.4	3.2	4.7	5.2	3.2	4.8	5.3
3.2	6.7	7.0	2.5	4.7	6.5	3.3	4.8	5.4	3.4	4.7	5.8
1.0	3.1	3.1	2.6	4.6	6.0	3.5	4.8	5.4	3.3	4.7	5.9
1.8	3.2	3.2	2.6	4.8	5.5	3.7	4.8	5.0	3.4	4.5	5.7
3.3	3.3	3.4	3.2	4.7	3.8	3.8	4.9	5.2	3.4	4.7	5.8
3.8	3.4	3.7	3.4		3.8	3.9	4.8	5.3			
4.0	3.4	3.8									
4.2	3.5	3.8									

on the one hand from the soft and semi-fluid condition with a larger per cent of water, and on the other hand from a more friable condition with a smaller per cent of water. When the load contained only 12 per cent of water, the motion of the block embedded in the sand was very nearly the same as that of the car. For the data given, the motion of the block for the higher frequencies was slightly but unmistakably greater than the motion of the car. At another time, when there was about the same per cent of water in the sand, the motion of the sand was just as unmistakably less than that of the car, altho by only a small amount. In the latter case the sand was probably somewhat drier and less adhesive than in the former case. In still another experiment, in which the sand was very much drier, containing probably less than 5 per cent of water, the amplitude of the motion of the block was distinctly greater than that of the car, at least for frequencies of 3 per second. Of course this does not refer to the motion of the loose sand on top. The motion of a layer 1 or 2 cm. deep of such loose, dry material was always much less than the motion of the car.

In the above discussion we have been solely concerned with the motion of the block embedded in the sand in the middle of the car. The sand on the bottom and near the ends of the car has but little relative motion with respect to the car. A board thrust downward into the sand showed by its motion that the relative motion of the sand with respect to the car increased from the bottom to the top. That the whole upper surface of sand in the car did not move together with the same speed was quite plain to direct observation. When the sand was very soft and wet, it rose and fell near the ends in the form of incipient waves, which, however, were not propagated away from the ends, three-

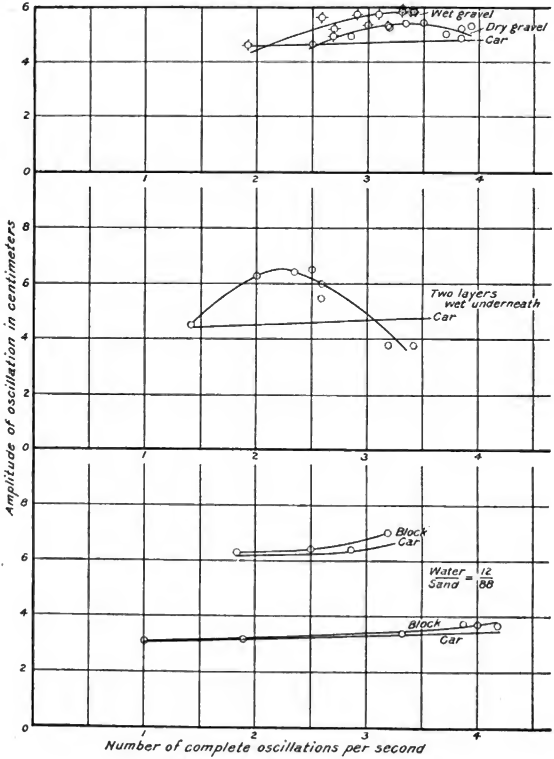

FIG. 62. — Graphic representation of results.

quarters of the surface remaining practically level during the vibration of the car. When the sand contained less water, the surface midway between the ends and the middle of the car was badly broken up by crevasses and ridges at right angles to the direction of motion.

It doubtless frequently happens in river valleys, coastal plains, or "made land" that a very soft water-soaked subsoil is covered with a crust of more solid ground. This condition of affairs was imitated on a small scale. A lower layer 13 cm. thick of very wet sand containing 20 per cent of water was covered by a piece of oilcloth, and upon this was placed a layer 12 cm. thick of much drier sand containing 10 per cent of water, and tamped into as compact a condition as possible. The block carrying the tracing pencil was embedded in this upper layer. If the whole load of sand had been like the top layer, it would have oscillated almost perfectly with the car. No such result was obtained with the two layers. When the car was shaken, it was apparent that there was still considerable freedom of motion in the lower layer. The upper layer moved as though it were floating on a semi-fluid mass. It rose and fell at the ends, and this motion extended to the middle, causing the block to rock back and forth, a result which was not obtained when the car contained a load of uniform consistency. The to-and-fro motion of the block was considerably greater than that of the car, for frequencies of 2 or 3 per second. For frequencies greater than 3, the amplitude of the block was less than that of the car. The results of this experiment are given in the tables on p. 330, while a plot of the same is included in fig. 62. The results, however, do not do justice to the possible destructiveness of such a motion. The rocking motion of the upper layer, as well as the violent manner in which it was broken up into fissures and ridges, seems to show that the destructive effect of the shaking motion of a semi-fluid mass may be increased when it is confined by a superincumbent layer of much more solid and compact material.

In the last experiment with the shaking machine, the car was loaded with coarse gravel. The gravel consisted of water-worn pebbles of all sizes up to 2 inches in diameter. It contained no clay nor sand to bind the gravel together. When this load of dry gravel was shaken, the block embedded in the gravel moved with the same amplitude as the car until the frequency reached 3 double vibrations per second. With higher frequencies the amplitude of the block was somewhat greater. Considerable water was then poured into the car, and it was again shaken with various frequencies. The results were similar to those obtained with the dry gravel, except that the relative motion of the gravel with respect to the car was nearly twice as great as in the case of the dry gravel. The data for these experiments are given in the table, while a plot of the same is given in fig. 62.

A consideration of the meager and more or less erratic data described above suggests various questions and criticisms. It has already been explained why more extensive experiments involving other materials were not undertaken. The erratic nature of the experimental data is not due to the method of experimentation employed, but to the uncertain and varying condition of the material with which the car was loaded. If, in the beginning of a series of experiments, the composition of the load was thoroly uniform, this was no proof that it remained so. A few moments of shaking sufficed to change to a greater or less extent this uniformity. When the material contained a large percentage of water, continued shaking caused the material close up to the ends of the car to pack and become somewhat drier; this was also true, tho to a much less extent, of the middle portion. The portion midway between the ends and the middle, where the relative motion of contiguous portions of the load was the greatest (thus causing fissures and ridges to develop), noticeably increased its content of water. This development of non-uniformity in the consistency and composition of the load is a sufficient explanation of the irregularity of the results obtained.

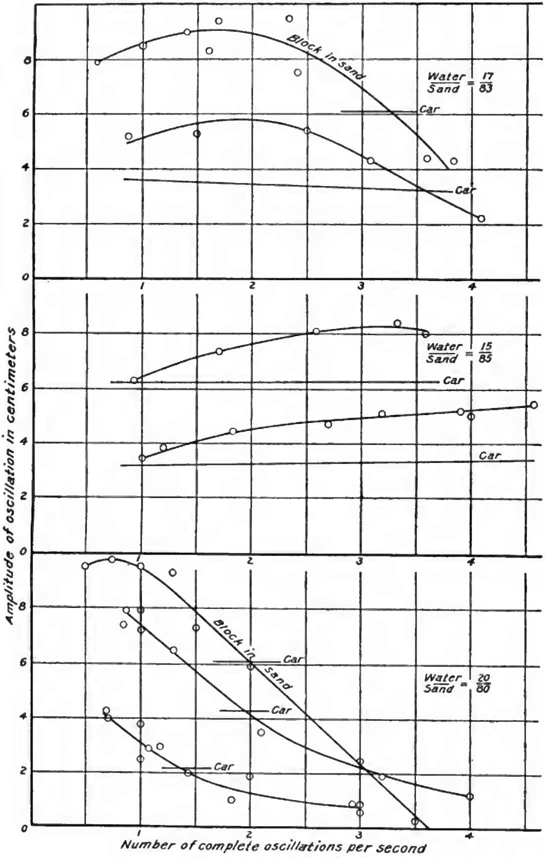

FIG. 63. — Graphic representation of results.

With regard to the scale on which the experiment was performed, the question naturally occurs: Would similar results have been obtained if the car were very much larger? One can not be certain, but it seems that such would have been the case if the frequency and amplitude of the car's motion were the same. Several experiments were performed with a depth of 15 cm. and 25 cm., and the results were substantially the same. The car was also divided by partitions running at right angles to the direction of motion, making a compartment of only half the length. The results tabulated below show that, at least in this case, the motion of the block embedded in the sand was not greatly affected by the presence of the partitions.

Length of car between partitions in cm.	101	49	101	101	49	49	101
Frequency in double vibrations per sec.	2.2	2.25	2.3	2.1	2.4	2.15	2.25
Amplitude of car in cm.	7.5	7.6	7.7	7.6	7.5	7.5	7.5
Amplitude of block in sand in cm. . .	11.9	9.3	11.3	10.8	10.8	11.4	11.8

In the experiment just described the material used contained 20 per cent water; with less water the partitions would doubtless have a greater effect in restricting the motion. It is also probable that with a larger car the relative motion of car and load would have been greater.

Another question which is likely to occur is: Does the solid or semi-fluid mass with which the car is loaded have a free period of its own which is comparable with the vibrations imprest upon it by the to-and-fro motion of the car? To elucidate this matter, the car was partially filled with water and the free period of gravitational waves determined experimentally. The frequency of such waves was found to be 1.06. However, the load, instead of being like water, was in all cases exceedingly viscous and plastic. This condition would in any case decrease the natural vibration frequency of the load, and in the present case the viscosity was so great that the load could not possibly have any vibration independently of the oscillatory motion of the car.

Finally the question may be asked: What is the explanation of the fact that the load on the car (or the major part of it) oscillates thru a greater amplitude than the car which causes the motion? At present I have no comprehensive explanation of this fact. It undoubtedly depends upon the inertia of the load, combined with the greater or less freedom with which it yields to imprest forces. The load in the car is set into motion by two sets of forces: (1) On account of the motion of the bottom of the car a tangential force is exerted on the bottom of the load and this is transmitted upwards by the rigidity of the load, or, exprest otherwise, by the mutual friction of successive layers of the load. (2) On account of the advancing motion of the end of the car the load receives a thrust which is transmitted thru the material by its resistance to compression. Sometimes one of these sets of forces is of greater importance, and sometimes the other. One would be apt to think the end thrust was of the greater importance, but this is certainly not always the case, for when the load consists of a *mound* not resting against either end of the car, the block embedded in the top of the mound may oscillate with a much greater amplitude than the car. (This was experimentally demonstrated.) In this case there can be no end thrust whatever. In some cases the end thrust may be more effective than the tangential force; this is probably the case when the frequency of motion is rather high.

To those interested in seismology the important question is: How do these experiments help to explain the greater destructiveness of earthquakes in regions where foundations are in alluvial soil than where foundations rest directly upon rocky strata? To pass from experiments upon a box containing half a ton of soil to the destructive effects of an earthquake is certainly a great leap. In taking such a step, one is very likely to make mistakes. However, it seems to me beyond question that a soft, semi-fluid mass of soil, containing a large amount of water and surrounded or partially surrounded by solid strata, will not oscillate with the same motion as the surrounding strata. Moreover, in the case of the frequencies ordinarily occurring in earthquake motion, the amplitude of the oscillation of such a semi-fluid mass is likely to be greater than that of the surrounding solid strata; also the reversal of motion or the acceleration during reversal is likely to be greater than in the case of solid strata. Finally the greater relative motion of such a soft or semi-fluid mass is not prevented by overlying strata of drier and more compact material.

REVIEW OF THE DISTRIBUTION OF APPARENT INTENSITY.

In the preceding pages, all the data significant of the distribution of the intensity of the shock of April 18, 1906, have been set forth in such detail as seemed to be warranted in a statement of fact. The general conclusions drawn from the data are represented graphically upon the intensity map No. 23. It is proposed here, however, to call attention to some of the more interesting and instructive phases of the distribution of intensity, and briefly to discuss their significance.

It is to be noted, in the first place, that the region over which the disturbance was felt, extending from the Pacific Coast to Central Nevada, and from southern Oregon to southern California, is one of varied physiography. In a consideration of the relation of the physiographic features to the distribution of intensity, it will be necessary to distinguish only two classes of features; viz., (1) the mountain and hill slopes, generally underlain by firm rocks and veneered for the most part with a thin mantle of regolith and soil; and (2) the valley-bottoms usually underlain by a relatively great depth of infilled alluvium in a little coherent condition, and for the most part saturated with ground-water.

The color bands on the map, indicating the gradation of intensity, show very considerable irregularities, or departures from the smooth curves which might reasonably be expected to obtain as the expression of such gradation of absorption of energy in homogeneous materials. To some extent such irregularities may be ascribed to the known lack of homogeneity in the firm elastic rocks of which the earth's crust is chiefly composed. But the irregularities referred to are too great to permit us to regard such lack of homogeneity in the underlying elastic rocks as an important factor in determining them. The irregularities are clearly related to the distribution of the valley lands.

GENERAL DISPOSITION OF THE ISOSEISMALS.

If now, before entering upon a consideration of these irregularities, we endeavor to ignore them, and so obtain a general conspectus of the color bands representing the gradation of intensity, the following features come out fairly clearly:

1. On the northeast side of the fault-trace, the zones of equal gradation of intensity show a tendency to belly out to the northeastward, opposite the middle portion of the fault-trace. This tendency is most pronounced in the grades from VII to II of the Rossi-Forel scale, and is apparent in all grades below IX.

The irregularities above referred to, associated with the distribution of valley lands, confuse somewhat the perception of this tendency, but do not detract from its reality.

2. As a partial statement of the same general fact, the color zones become distinctly narrower, and their boundaries converge, as they approach the coast north of Eureka. This feature of the distribution of intensity clearly suggests that the isoseismal curves close in and swing around the end of the fault, and that there is, therefore, no indication of a submarine prolongation of the fault beyond its known extent on the mainland in Humboldt County.

3. The zones of equal gradation from IX to V of the scale are narrower at the southern end of the fault-trace than at the northern end, and they close around the end much more closely. This fact is suggestive of less depth of disturbance at the southern end of the fault. But the general disposition in the south of the zones ranging from V to II is not essentially dissimilar to those in the north.

4. The disposition of the isoseismal curves along the coastal territory between Point Arena and Shelter Cove indicates that the trace of the fault on the sea-floor lies but a few miles off shore, and that its course partakes of the nature of a very obtuse sigmoid curve, approximately parallel to the trend of the coast. It follows from this inference that the fault observed in Humboldt County is continuous with that extending from the vicinity of Point Arena southeastward. No facts have come to light which weaken this conclusion, altho all the facts have been diligently sought for.

5. On the southwest side of the fault, the territory upon which it has been possible to trace the isoseismals, particularly those ranging above VI, is very much smaller than on the northeast side. In so far as the territory available is representative of the entire southwestern crustal block, it appears, chiefly from the isoseismals covering portions of San Mateo, Santa Cruz, San Benito, and Monterey Counties, that the intensity diminished much more rapidly to the southwest than it did to the northeast. This interesting fact suggests that, of the two crustal blocks differentially displaced on the fault, the southwest block was perhaps the more passive. It may, however, indicate that the apparent intensity, as interpreted from effects on structures and objects, is a function of the character of the underlying rocks; since on the southwest side of the fault-trace there are extensive areas of highly elastic granitic rocks, while on the northeast side of the fault-trace these granitic rocks are deeply buried by sedimentary formations and appear nowhere at the surface west of the Sierra Nevada.

6. The zones of equal gradation of intensity, ranging from X to VII, are fairly evenly spaced, tho broadening with diminishing intensity; from VII to VI the zone is notably broader, particularly in the northern portion of the region affected; and from VI to II the broadening of the zones is very marked.

RELATION OF APPARENT INTENSITY TO VALLEYS.

The generalizations above set forth are independent of the irregularities in the isoseismal curves associated with the valleys. We may now inquire into the relationship which obtains between the valleys and the distribution of apparent intensity.

The most northerly locality where this relationship appears is on the flood plain of the Eel River, near the coast, in Humboldt County. The lower part of the Eel River Valley has been carved by stream erosion out of a synclinal trough of Pliocene strata having a thickness of over a mile. The syncline is flanked by older and much harder sandstones which are probably of Franciscan age. On the south of the valley these older sandstones constitute a bold mountain ridge, stept with terraces, which terminates in Cape Mendocino. The north side of the ridge has an east and west trend, and the Pliocene strata extend well up on its flanks. There is no suggestion of a fault on this side of the ridge, the trend being determined by the axis of the synclinal fold. The other side of the flood plain has a less regular northwest-southeast trend, converging upon the south side in the vicinity of Rio Dell. The flood plain is thus bounded by a wide trumpet-shaped but asymmetric contour terminating in lagoons and sand beaches south of Eureka. The depth of the alluvium of the flood plain is not known, but the features of the region suggest that it is undergoing subsidence and the alluvium may be several hundred feet thick. On this flood plain the apparent intensity was notably higher than on the surrounding slopes. This is shown by the extent of destruction in Ferndale and other towns situated upon it, and by the rupturing and deformation of the alluvium of the flood plain itself, particularly in its lower part near the sea, and by the lesser destruction in the surrounding higher country. The data regarding the intensity on the high ridge to the south are scant, owing to the fewness of habitations, but on the Pliocene terrane on the northeast side of the flood plain, there was a distinct drop in the degree of destruction, altho this terrane consists largely of strata which are only partially indurated and but little coherent.

The apparent intensity of the lower part of the Eel River flood plain grades from X to IX, tho in general nearer IX than X. It is surrounded by a belt of country where the intensity grades from IX to VIII. This belt has a width of a few miles on the Pliocene terrane to the northeast of the flood plain, and probably scarcely extends to the harder Franciscan rocks of the ridge to the south. The facts thus necessitate the recognition on the intensity map of an area of high intensity, including a range from X to VIII, in the midst of a region where the prevailing intensity ranges only from VIII to VII. This, as will be seen in what follows, is typical of all the more important alluviated valleys of the Coast Ranges, and indicates clearly that the apparent intensity for such situations is a function of the underlying formations.

On the more limited flood plain of the Mattole River at Petrolia, the destructive effects were even more intense than at Ferndale, and in marked contrast to those apparent in the few scattered houses on the rocky upland. But little can be inferred from this contrast, since Petrolia is situated on the projection of the fault-trace, and only a few miles beyond the most northerly point to which it has been mapped.

The town of Willets is at the headwaters of a branch of the Eel River on a flat alluviated valley-bottom several miles in extent. The situation and character of the valley are such as to suggest that it is a filled-in lake basin. The ground-water below the valley-floor stands within a few feet of the surface. The town is 26 miles from the coast at Mendocino City, and not less than 30 miles from the fault-trace; yet the apparent intensity was not less than IX of the scale, or equal to that which prevails on the hard rocks in the zone, the distal border of which is usually not more than 6 miles from the fault-trace and often much less. Between Willets and the coast the intensity had diminished from X in the vicinity of the fault-trace to less than VII. This rapid rise from less than VII in the territory immediately to the west, to IX on the valley-floor, with no evidence of other factors intervening, and no evidence of similarly high intensity on the rocky slopes surrounding the valley, again indicates that the apparent intensity is a function of the character of the valley-floor.

A similar condition prevails in the valley in which Ukiah is situated, 20 miles to the south of Ukiah. The physiographic features of the valley are described by Mr. George McGowan in his report describing the effects of the earthquake at Ukiah. The town is about 27 miles from the fault-trace, and in this interval the intensity had diminished from X to less than VII. In Ukiah, which is on the old flood plain of the Russian River, near the middle of the valley-floor, the intensity rose to between IX and VIII. Here again, there can be little doubt as to the influence of the underlying formations upon the destructive effects of the shock. This conclusion is supported by the time at which the shock was felt. Ukiah is one of the few places where satisfactory time observations were obtained.

At the International Latitude Observatory, Dr. Townley reports that he was awakened by the shock and lookt at his watch, finding the time (corrected) to be $5^h\ 12^m\ 30^s$, and he is of the opinion that the shock commenced at $5^h\ 12^m\ 17^s$. This accords fairly well with the time the shock was due at Ukiah, and affords no suggestion that the local high apparent intensity may have been due to a local earthquake.

Another valley area of high intensity is on the west side of Clear Lake, extending from Kelseyville to Upper Lake. Lakeport, in the central portion of this area is 36 miles distant from the fault, with 2 mountain crests intervening. In this interval the intensity had diminished from X to less than VII, but at Lakeport and Upper Lake it rose to IX. The topographical and geological maps of the Clear Lake district, published by Becker,[1] show that Lakeport and Kelseyville are on an alluvial plain, the underlying deposits of which are of Quaternary age; and the same conditions prevail at Upper Lake. Between this area of alluvium and Bartlett Springs, on rocky ground, 10 miles to the east of Upper Lake, the intensity dropt to VI. At Lower Lake, situated on Tejon sandstone, the intensity had similarly dropt to VI; and these intensities are about the normal for the distances at which Bartlett Springs and Kelseyville lie from the fault along the coast. At Highland Springs, the intensity was between VII and VI, which is also about the normal for its distance from the fault. It thus appears that the high apparent intensity was confined to the alluvial or recent lake deposits of the area about Lakeport. These facts indicate that the high apparent intensity for this area was probably not due to a local earthquake, coincident or nearly so with the main shock, but that the destructive action of the latter was locally augmented by conditions inherent in the underlying incoherent deposits. For if there had been a local dislocation, its effects would undoubtedly have made themselves manifest over a wider area than that occupied by these deposits. The character of the shock, as described by those who experienced it in the vicinity of Clear Lake, agrees, moreover, with that of the shock emanating from the fault at the coast. Becker's geological map of the district shows no faults traversing it.

In general, then, while from the nature of the case it is not possible to deny positively that a local earthquake may have occurred on the morning of April 18, 1906, at the same time as the main shock, no evidence appears to sustain that view. On the other hand the evidence here as elsewhere supports the belief that the apparent intensity is a function of the underlying formations to the extent manifested in this district.

Coming now to Santa Rosa Valley, we encounter an interesting case of high intensity, associated with an alluvial valley-bottom. The valley may be described as an oval-shaped area, extending for 24 miles from Healdsburg to the vicinity of Penn's Grove, with a maximum width of 8 miles on a line lying between Santa Rosa and Sebastopol. The general trend of the central axis of the valley is about N. 30° W. It is thus not far from parallel with the general trend of the fault along the coast. Over a considerable expanse the valley-floor is perfectly even, and appears level to the eye. At its widest portion, however, it has a slope from an elevation of 170 feet above sea-level in the eastern part of the city of Santa Rosa, to about 50 feet above sea-level, a descent of 15 feet to the mile. In this section there are no terraces, but a perfectly even profile. To the north of Santa Rosa, however, the floor of the valley is less even, and it is stept in a few broad terraces, the lowest of which is the present flood plain of the Russian River.

The geomorphogeny of the valley is not altogether simple; the primary fact in its development, however, is that it has been carved by stream erosion to its full width out of a great syncline of Merced (late Pliocene) strata.[2] The upturned edges of these Merced strata, planed down to an even but now somewhat dissected surface, constitute the floor of the upper terrace lying to the north of Mark West Creek at an altitude of about 200 feet above the flood plain of the Russian River. On a somewhat lower terrace is the town of Windsor. South of Mark West Creek, the valley is in general deeply alluviated and the wells a little to the east of the city of Santa Rosa (150 feet deep) show that the alluvium is saturated with ground-water to within a short distance of the surface. The distribution of this ground-water thruout the valley is, however, not well known, no systematic investigation ever having been made. On the western side of the valley from Sebastopol northward to Mark West Creek, the drainage is stagnant and gives rise to the Laguna de Santa Rosa. This lagoon is a drowned water course in free connection with the trunk drainage of the Russian River, and is indicative of a deformation of the valley surface whereby the western side has been deprest below the base-level established by the Russian River. From these statements it will be apparent that the whole of the floor of the Santa Rosa Valley is not alluviated, but that portions of it — particularly that portion lying between Mark West Creek and Healdsburg and east of the flood plain of the Russian River — is a terraced platform carved out of the Merced terrane.

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[1] U. S. Geological Survey, Monograph XIII.

[2] Cf. Osmont, Bull. Dept. Geol., Univ. Cal., vol. 4, No. 3.

Now the notably high apparent intensity of the earthquake shock was confined to the alluviated portion of the valley-floor. The 2 centers of population which suffered most severely were Santa Rosa and Sebastopol. At Windsor, situated on the terrace cut in the Merced rocks, the intensity was distinctly lower. Healdsburg, at the northern extremity of the valley, is also on alluvium and the intensity was here again high, tho not quite equal to that at Santa Rosa and Sebastopol. The town of Guerneville, on the old flood plain of the Russian River, below the Santa Rosa Valley, suffered most severely; while the cemetery of the town, but a short distance away, on a rocky terrace 190 feet above the town, was affected in a distinctly less degree, only one monument having been overthrown, and a few moved on their pedestals. The rapid diminution of intensity on passing from the alluvium to the rocky slopes, thus specifically illustrated at Guerneville, is characteristic of the borders of the Santa Rosa Valley. To the east of the city of Santa Rosa, this diminution is so rapid that the gradation of intensity can not be adequately exprest upon the intensity map. Under these circumstances it is difficult to avoid the conclusion that the severity of the earthquake shock on the alluvium of the Santa Rosa Valley is in large measure referable to the character of the ground. Were a local shock a factor in the case, we should expect that the high intensity would not be limited to the alluviated area, but would also be manifested on the surrounding mountain slopes. This expectation not being realized, the hypothesis of an independent local shock stands without support. The general position of the isoseismal curves off the valley-bottoms is not notably affected by the high apparent intensity in the valleys. In arriving at the conclusion that the high apparent intensity in this valley is referable in large measure to the character of the ground, it is not thereby intended to exclude other contributory factors. A theoretical discussion of the effect at the surface of the earth of a concussion at a point within the crust shows that for a certain path of emergence the horizontal jerk of the emerging earth-wave, and, therefore, the destructive effect in general, would be at a maximum. The fact that the earthquake under consideration was due not to a concussion at a point, but to a jar developed by movement on a plane at least 270 miles long, reaching to the surface and of unknown depth, renders the application of this doctrine difficult and of questionable value. Nevertheless, the tendency, which is demonstrable in the ideal case, would also exist in the more complex actuality; and it is by no means impossible that the zone of maximum destruction may fall in a general way within the Santa Rosa Valley, and would thus be a factor conducive to excessive destruction, in addition to the factor inherent in the character of the ground. This suggestion, to have weight, should be corroborated by observations in other portions of the general zone of destructive effects, and it must be confest that satisfactory corroboration is lacking.

While the geology of the Santa Rosa Valley has not been mapped in detail, owing to the lack of topographic maps, it has been carefully studied, particularly from the structural and stratigraphic point of view, by Mr. Vance Osmont,[1] and no fault traversing the valley was found by him. The underlying structure, so far as has been made out, is as already stated that of a broad, rather simple, synclinal fold. It has also been indicated that the surface of the valley has been subjected to recent deformation, whereby the western side has been deprest below the local base-level. This may be taken as an indication of the persistence of the compressive forces which originally gave rise to the syncline. If, now the underlying rocks of the valley were in a state of synclinal stress, the relief of that stress afforded by the dislocation along the line of the Rift might give rise to an elastic disturbance of the ground which would be additive to the shock generated at the fault along the Rift.

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[1] Bull. Dept. Geol., Univ. Cal., vol. 4, No. 3.

But none of these suggestions, whether of contributory shock, or an unrevealed fault, or of coincidence of the valley with a vaguely defined zone of maximum horizontal jerk, or of sudden relief from synclinal compression, are sustained by satisfactory evidence. They are possibilities which, with the facts before us, it is possible neither to affirm nor to deny. The reference to them in this place is only excusable on the ground that they are suggestive of lines of inquiry which may perhaps be profitably undertaken at some future time. On the other hand, the influence of the character of the ground upon the apparent intensity is sustained by cumulative evidence.

In Sonoma and Napa Valleys, the disposition of the isoseismals is very evidently determined by the contour of the valleys, the high intensities running far up the valleys within areas of lower intensity on either side. In Sonoma Valley the upper and lower parts are alluviated, while the middle part is not; or, if so, only to a slight extent, and it is being trenched by the stream which flows thru it. The floor of Napa Valley, on the other hand, is alluviated thruout, save for some rocky spurs and isolated rocky hills which occur along portions of the sides of the valley. The intensity diminishes in the upper part of Napa Valley, in the vicinity of Calistoga, where the alluvial deposits thin out, notwithstanding the fact that Calistoga is somewhat nearer the fault along the Rift than is Napa City, at the lower end of the valley, and notwithstanding the fact that Calistoga is approximately on the line of the Mount St. Helena fault described by Osmont. If the relatively high apparent intensity of Napa Valley were in any way referable to a local earthquake on a fault traversing the valley, we should not only expect the effects to be manifested on the rocky slopes of the valley, as well as upon its floor, but would also expect higher intensities on the line of the only well-defined fault known to traverse the valley. Neither of these expectations is realized, and upon the slopes of Mount St. Helena, in the vicinity of the fault which traverses its western front, the intensity was notably low—not higher than VI. We are thus again forced to fall back upon the character of the ground as the immediate cause of the high apparent intensity on the alluviated valley-floor, particularly in the lower part of the valley.

Specific and instructive instances of the influence of the character of the ground upon the apparent intensity of the shock are afforded by the cities of Petaluma and San Rafael. Each of these cities is built partly upon rock and partly upon the alluvium of the tidal marshes of the San Francisco Bay. Petaluma is situated at a distance of 14 miles from the fault, and San Rafael at a distance of 9 miles. In both cities the damage to buildings, chimneys, etc., was notably less upon the rock than upon the alluvium, altho the latter can not in either case be supposed to have any great thickness at the base of the hills. (See fig. 64.)

In the city of San Francisco the detailed study of the distribution of intensity, so successfully carried out by Mr. H. O. Wood, affords a conclusive proof of the paramount influence of the character of the ground in determining the high apparent intensities which affected portions of the city. On the made land in the vicinity of the Ferry Building, about 9.5 miles from the fault, as well as on the tidal marsh land, and along Mission Creek and Lagoon, between 7 and 9 miles from the fault, the intensity was X of the Rossi-Forel scale. But on the rocky top of Telegraph Hill, near the ferries, the intensity was scarcely higher than VII. On the sandstone cliffs at Point Lobos, about 3 miles from the fault, it was about VIII; and on the summits of the chert hills in the central part of the city and county of San Francisco, 5 to 6 miles from the fault, it was about VII. On the alluvium of Mission Valley, at distances of from 6 to 9 miles from the fault, the intensity varied from less than VII to between VIII and IX.

Under similar conditions of ground, the shock was greater nearer the fault; but there was much greater contrast between the damage produced by the shock on the summit of Telegraph Hill and that in the vicinity of the Ferry Building, at like distances from the fault, than there was between the damage near the ferries and that in the immediate vicinity of the fault. Thus, notwithstanding the general tendency of the intensity to diminish with increasing distance from the fault, it seems to be unquestionable that the degree of intensity which prevailed at any locality in the city depended chiefly on whether the underlying formations are firm rock or incoherent material more or less saturated with water. It would even seem possible to discriminate slight differences of apparent intensity on different kinds of firm rock for the same distance from the fault. Thus the chert hills appear to have suffered less disturbance that those where serpentine

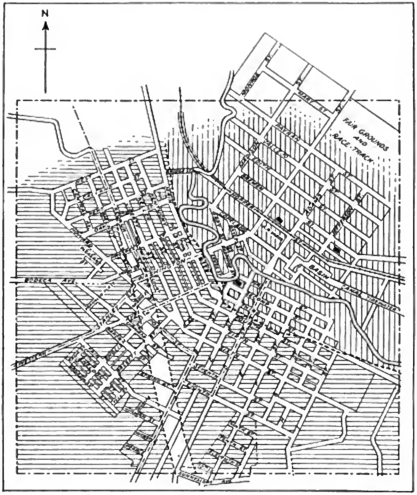

FIG. 64.—Distribution of intensity in Petaluma. Vertical lines represent area of low alluvial land, on which nearly all chimneys were damaged. Horizontal lines represent slopes underlain by rock, on which about half the chimneys were damaged. The solid black areas and dots represent exceptionally severe damage. The blank area inclosed by dotted lines represents a belt of practically no damage. By R. S. Holway.

outcrops; and the sandstone areas were more disturbed than the serpentine. But these differences are minute.

In the case of the made land and old marsh land of San Francisco, where the apparent intensity reached X, there can be no question as to possible local shocks, since the excessive disturbance was so strictly limited to the area lying outside of the original shore line and marsh border.

In the low ground about San Francisco Bay to the south of the city, we have another instance, on a rather large scale, of high apparent intensity determined by the incoherent water-saturated condition of the underlying formations. San Francisco Bay in general, and the southern portion of it in particular, lies in an alluviated valley which has been deprest so that its central portion is now below sea-level. This submerged valley-floor passes insensibly into the Santa Clara Valley which encloses it on the south and extends southward between the Santa Cruz and Mount Hamilton ranges. Treating San Francisco Bay and Santa Clara Valley as one physiographic feature, it may be stated, without going into the evidence in detail, that depression and alluviation have both been greater in the southern end than in the northern. This southern portion of the valley constitutes a great artesian basin, and many wells have been sunk in it. The deprest trough is not, however, wholly filled by alluvium, since several wells have past through late Quaternary strata containing marine fossil remains. It would appear, from the sections revealed by these wells, that with the progress of subsidence, marine deposition alternated with alluviation. The deposits, whether marine or alluvial, appear to be incoherent or unconsolidated, consisting of clays, sands, and gravels, in layers of irregular thickness and extent. Many wells have past through several hundred feet of such materials without reaching bedrock. One well, on the edge of the marsh near Alvarado, reached rock at a depth of 730 feet. At the sugar-mill at Alvarado, and at the Contra Costa pumping plant, in the same vicinity, there are several wells from 300 to 400 feet deep, passing thru clay, sand, and gravel without reaching bedrock. At Roberts' Landing there are 2 wells, one 574 feet deep and the other 540 feet deep, which past thru alternations of clay, sand, and gravel, but did not reach bedrock. A well 1.5 miles south of Milpitas past thru 11 layers of gravel aggregating 166 feet and 12 layers of clay aggregating 218 feet — total depth 384 feet — but did not reach bedrock. The wells in the vicinity of San Jose range in depth from 35 to 500 feet as a rule. One well on the bank of Guadaloupe Creek, however, was sunk to a depth of 1,100 feet, but did not penetrate bedrock. A well at Stanford University is in gravel at 412 feet. On the west side of the Bay there are several hundred wells, most of them less than 100 feet in depth, while the deep ones are usually a little more than 300 feet. Wells are even bored in the bottom of the Bay and an abundant supply of fresh water is obtained from them. These brief statements will be sufficient to afford a general idea of the extent to which the valley has been deprest and filled in with deposits as yet unconsolidated. To the south, the rocky floor of the valley appears at the surface in the vicinity of Coyote, 12 miles south of San Jose. Beyond this, however, the valley again opens out and is deeply alluviated.

On the floor of this valley, from San Bruno Mountain southward, on both sides of the Bay, and southward a few miles beyond San Jose, the intensity was abnormally high. On the rocky slopes between the western edge of the valley-floor and the fault, the intensity had dropt from X at the fault to VIII at the base of the hills. On the valley-bottom it again sharply rose to IX. On this ground were Stanford University, Redwood City, San Mateo, the 44-inch pipe of the Spring Valley Water Company, San Jose, Agnews, Milpitas, and Alvarado. On the eastern side of the Bay the intensity of IX did not persist to the base of the hills, but extended only about halfway from the shore line to the edge of the valley. There was therefore a distinctly diminishing intensity in approaching the base of the hills on this side of the valley. But at the base of these hills lies one of the dominant faults of the country — the fault upon which movement took place, with rupture of the ground, producing the earthquake of 1868. It would seem that, if local earthquakes were to be invoked to explain the high intensity of the alluviated valley-bottoms, here was a fine opportunity for an illustration of that doctrine. But the seat of the disturbance of 1868 was perfectly passive in 1906. The intensity diminished eastward right up to the fault-trace; and there is no suggestion that the disturbance along the San Andreas Rift affected it in the slightest degree. This being the case, there appears to be no recourse but to ascribe the normal apparent intensity about the southern part of San Francisco Bay to the character of the underlying formations as in other valleys before described.

To the west of the San Andreas fault in San Mateo and Santa Cruz Counties, the apparent intensity diminishes on the firm rocks more rapidly than to the east of the fault, but it rises very notably on the alluvial fan of Pilarcitos Creek at Half Moon Bay, and in the alluviated valleys of San Gregorio and Pescadero Creeks. Going westward down Pilarcitos Canyon, the apparent intensity drops from X at the fault to less than VII within 4 miles of the fault; but along the coastal fringes of alluvium which lie between the hills and the sea, it rises again to VIII at Spanish Town and to IX on the flats below the town. In the valleys of San Gregorio and Pescadero Creeks an apparent intensity of from VII to VIII extends for 4 miles and 3 miles, respectively, into an area of hill lands where the prevailing intensity is from VI to VII. The geology of this region, the Santa Cruz Quadrangle, has been mapped by Prof. J. C. Branner, and no fault is known at Half Moon Bay. Farther south the San Gregorio fault crosses the mouth of San Gregorio Valley and the middle part of Pescadero Valley, with a course parallel to the trend of the coast or transverse to the axes of the valleys. But the high apparent intensity in the bottoms of these valleys can not be referred to a local earthquake due to movement on this fault, since on either side of both valleys, in the immediate vicinity of the fault, it drops to below VII; while a few miles farther south on the same fault the apparent intensity drops to VI.

At Santa Cruz a portion of the city is built partly on a series of broad wave-cut terraces in the bituminous shale of the Monterey series and partly on the alluviated bottom-lands of San Lorenzo River. The contrast in apparent intensity in these two portions of the city is marked. In that portion which is situated upon the terraces the apparent intensity ranges from VII to VIII, while on the bottom-lands of the river it rises to from VIII to IX. It thus appears again, from a consideration of these four cases on the coast extending from Half Moon Bay to Santa Cruz, that the character of the material in the alluviated valley-bottoms has exercised a dominant influence in determining the apparent intensity of the earthquake shock, and that there is nothing in the facts to suggest that any other factor has played an important rôle.

The finest illustration of the influence exercised by alluvium in the production of high apparent intensity is that afforded by the valley of the Salinas River and its extension to the valley of the lower portion of the Pajaro River. The Salinas Valley is one of the notable physiographic features of the Coast Ranges. It lies between the Santa Lucia and Gavilan Ranges. It is deeply alluviated and strikingly terraced, particularly in its lower part. The course of the valley was probably determined originally by the fault along the eastern base of the Santa Lucia Range. The river discharges into the Bay of Monterey about its middle part, a few miles south of the mouth of the Pajaro River. On the flood-plain tracts of both rivers, and along the beach of the Bay of Monterey, the intensity was IX. This extended up the river for several miles above the town of Salinas. There were extensive fissures in the alluvium as far as Gonzales, with slumping of the ground toward the river trench. Damage of structures, indicating an intensity of VIII, extended up the valley as far as Chualar; and the limit of intensity, VII, was reached only at King City, 45 miles above Salinas; VI in the vicinity of San Ardo, 65 miles; and V at Pass Robles, 99 miles above the same point. The isoseismals drawn thru these points are almost parallel to the river, the intensity to the east and west diminishing rapidly. The town of Salinas is about 13 miles distant from San Juan, in a direction normal to the fault-trace. On the northern end of the Gavilan Range, which intervenes between the two valleys, the apparent intensity dropt to V and then rose rapidly to IX in the Salinas Valley. The limitation of the high apparent intensity to the valley-floor, the practically symmetrical parallelism of the isoseismals to the median line of the valley, and the diminution of the intensity with the thinning of the alluvium and the constriction of the valley upstream, all indicate dependence of the character of the shock upon the constitution of the underlying formations, and suggest no other factor.

Still farther south in San Luis Obispo and Santa Barbara Counties, far beyond the isoseismal IV, an apparent intensity of IV is indicated by the effects observed in the valley-lands at San Luis Obispo, Edna, Arroyo Grande, Pismo, Santa Maria, Casmalia, and Lompoc. In the flat alluviated valley-bottom in which the town of Hollister is situated, about 8 miles east of the southern end of the fault at San Juan, the apparent intensity rose to IX, but diminished very rapidly on the hill lands immediately to the east of the valley to VI, which appears to have been the normal intensity for the mountainous tract between Hollister and the San Joaquin Valley.

Farther southeast there was a similar but less marked rise in the apparent intensity at Lonoak, Priest Valley, and Hernandez, all of these being on alluviated bottoms.

In the alluviated valleys to the east of the Berkeley Hills, the apparent intensity was abnormally high and the area occupied by these valleys constitutes an isolated area in which the intensity ranges from VII to VIII in the midst of a belt in which the range is from VI to VII. At Pleasanton the intensity was somewhat higher than at Sunol, altho the latter is nearer the fault of April 18, 1906, and is situated, moreover, on the line of an old fault which traverses the west side of Livermore Valley and extends up Calaveras Valley into the Mount Hamilton Range. At Livermore, in the more open part of the valley, where the alluvium is deeper, tho 8.5 miles farther from the seat of disturbance, the intensity was about the same as at Sunol. At Martinez, on an alluviated embayment of Suisun Bay, the damage due to the shock was much greater than in neighboring towns situated on rock, even when the latter were nearer the fault. Beyond Martinez to the eastward there is a very marked bulge to the east of Suisun Bay, in the isoseismal VII, which can be attributed only to the low and marshy character of the ground. The apparent intensity at Antioch was a degree higher in the scale than that at Mount Hamilton, altho it is double the distance from the fault of April 18; and altho there are several old faults in the vicinity of Mount Hamilton and none are known near Antioch.

The influence of the valley-lands upon the apparent intensity is well shown on a large scale in the disposition of the isoseismal curves about the Sacramento Valley. In the mountains to the west of the Sacramento Valley the apparent intensity ranges in general from VI to V; but on the floor of the valley eastward to beyond the Sacramento River, it is very uniformly about VI or VI+.

The most interesting case of high apparent intensity in a valley-bottom remote from the San Andreas fault is that of the San Joaquin Valley. This case merits especial consideration, since of all the valleys here considered it is the one which is most suggestive of the occurrence of a local earthquake, distant from, tho connected with, the main movement on the San Andreas fault. While the suggestion is strong, however, the evidence is not conclusive of the occurrence in this region of a quasi-independent earthquake; and all that can be done is to indicate the evidence which points that way, and cite certain facts which detract from the force of that evidence and tend to correlate the locally high intensity in the San Joaquin Valley with similar high apparent intensities in other valleys thus far discust.

The apparent intensity on the floor of the Sacramento Valley, as has been stated, ranges about VI + of the scale. This is somewhat higher than at several points in the adjacent Coast Ranges to the west, and the difference is ascribable to the alluviated character of the valley-floor and the water-saturated condition of the alluvium. As we follow the Sacramento Valley southward into the San Joaquin Valley, it converges upon the San Andreas Rift, and we should naturally expect an increase in the intensity by reason of the diminution of the distance from the seat of disturbance. This expectation is in a measure realized by an eastward bulge in the isoseismal VII opposite Suisun Bay, and by the somewhat higher intensity at Tracy and Westley than at Sacramento and Stockton.

Southward from Westley, however, the apparent intensity increases at a rate which can not be referred to the slight approximation of the region to the seat of the main disturbance. At Crow's Landing the apparent intensity is VII; at Newman it is VIII; at Volta it is VIII +; and at Los Banos it is IX. These points lie on the west side of the valley between the San Joaquin River and the flanks of the Coast Ranges. South of Los Banos, on the valley floor, settlements are very few, and information as to the apparent intensity is unfortunately lacking over an extensive territory. At Coalinga, however, the apparent intensity is VII, indicating that the abnormally high figures prevail over the western side of the valley from Crow's Landing to southward of Coalinga, a distance in a north and south direction of not less than 100 miles. That the high apparent intensity was not wholly confined to the valley-floor, but also extended into the flanks of the Coast Ranges, is shown by the remarkable series of landslides which were started by the earthquake for a distance of about 23 miles northwestward from the vicinity of Cantua, reported by Mr. S. C. Lillis, and described by Prof. G. D. Louderback in another part of this report.

Now Los Banos, where the apparent intensity was highest, is distant 40 miles from the nearest point on the San Andreas fault at San Juan, its southern end. It is nearly 34 miles in an air-line from Hollister, the nearest point to the westward having a similarly high apparent intensity. In the Coast Ranges between Hollister and Los Banos, the intensity was as low as V.

These facts are suggestive, as already stated, of a local disturbance at or about the same time as the main movement along the San Andreas fault.

Certain circumstances detract, however, from the force of this suggestion, and indicate another possible explanation which, it must be confest, is not very conclusive in view of the remoteness of Los Banos from the seat of disturbance. The portion of the San Joaquin Valley in which Los Banos lies is undoubtedly an underground water reservoir. It lies at the base of the alluvial fans of the Coast Ranges where the streams sink, and the waters of the San Joaquin River maintain the water-table at no great distance below the surface. As shown by the experiments of Prof. F. J. Rogers, described in another part of this report, water plays an important part under certain conditions in increasing the amplitude of the earth vibrations and, therefore, their destructive effect. In this respect the region about Los Banos would be particularly favorably conditioned for the development of high apparent intensities, as inferred from destructive effects. The general conditions are quite analogous to those in the Salinas Valley, in the bottom-lands of the Pajaro River and the Russian River, and in the region about the south end of San Francisco Bay. The chief difference is in the greater remoteness of the Los Banos region from the seat of disturbance, if only one such seat be assumed.

Another circumstance which weakens the suggestion of a local earthquake is the failure of the isoseismals below VII to carry out the suggestion by bulging into the Coast Ranges on the west or the flanks of the Sierra Nevada on the east. In the latitude of Los Banos, the high apparent intensity was confined to the valley-floor, altho farther south, near Cantua, this can not be affirmed. In view of the experiments of Professor Rogers, it seems probable that in the near future, by an active prosecution of such experiments coupled with close field observation, we shall arrive at an arithmetical expression for the coefficient which will enable us to reduce the apparent intensity of water-saturated alluvium to the true intensity due to vibration in homogeneous elastic rock. When that coefficient becomes available, it will perhaps be possible to determine whether or not the destructive effects exemplified in the San Joaquin Valley at Los Banos are referable to the conditions of the ground or to a local seismic disturbance. Until then the question must remain an open one. Analogy with other valley lands nearer the fault, where high apparent intensities are referable, both on the field evidence and in the light of Professor Rogers' experiments, to local conditions, militates against the hypothesis of a quasi-independent earthquake. The remoteness of the region from the known fault and the high intensities on the flanks of the Coast Ranges indicated by the new landslides at Cantua, favor that hypothesis; but no positive conclusion can be reached at present.

RELATION OF APPARENT INTENSITY TO KNOWN FAULTS.

Altho the geology of California has been studied in detail at but few localities outside of the gold belt of the Sierra Nevada, yet the general reconnaissance work that has been done by various geologists has brought to light many of the important faults in the state. Such as are known are indicated on map No. 1, without any attempt to discriminate between the varying degrees of certainty with which their existence has been determined. The map serves the double purpose of bringing together for the first time our knowledge of the distribution of faults thruout the state, and of illuminating a brief discussion of the relation of apparent intensity to fault-lines. On 4 of these faults there have occurred 5 severely destructive earthquakes within the last 50 years. It thus behooves students of Californian seismology to become familiar with these structural features of the state. A recent account of the Calabrian earthquake of September 8, 1905, dealing particularly with the distribution of intensity,[1] and the relation of that distribution to fault-lines known or inferred, gives an especial interest to the consideration of the faults of the Californian region at this time. In the preceding section of this report, it has been shown very definitely that abnormally high apparent intensities were developed on the valley-bottoms, and the cause of this has been referred in a general way to the incoherent and water-saturated condition of the materials underlying these valley-bottoms. In Calabria, in the account referred to, Professor Hobbs correlates the zones of exceptionally high intensity with lines of ancient faults, which in some portions of the region are known on geological evidence to exist, and in others are supposed to exist because of the high intensities manifested. He does not recognize the character of the underlying formations as an important factor in producing different degrees of intensity, as inferred from destructive effects at the surface. In this respect his conclusions do not harmonize with those arrived at in the study of the California earthquake of April 18, 1906. It thus becomes a matter of interest to ascertain what, if any, influence was exercised by the known faults of California, other than that which was the seat of disturbance, upon the distribution of apparent intensity, independently of that which was clearly due to the character of the geological formations. This question has been touched upon incidentally in the discussion of the relation of the valleys to distribution of apparent intensity, but it will be of advantage to review the facts here more systematically, tho quite briefly.

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[1] W. H. Hobbs, The Geotectonic and Geodynamic Aspects of Calabria and Northern Sicily. Leipzig, 1907.

In southern Oregon and in northeastern California, in Modoc, Shasta, Lassen, and Plumas Counties, the shock was so uniformly feeble that there is no suggestion of locally high intensity due to any cause. The same general statement is true of northeastern California, in Del Norte, Siskiyou, Humboldt, and Trinity Counties; but in this region some of the faults, particularly that of Redwood Mountain, were not farther from the seat of disturbance than certain localities farther south, where abnormally high apparent intensity was developed on valley-bottoms. If the Redwood Mountain fault had been a locus of movement, there can be little doubt, altho the settlements in that region are few and scattered, that we should have heard of the severity of the shock. No evidence, however, has come to hand indicative of any exceptional severity on or near the line of that fault.

Along the eastern front of the Sierra Nevada, from Honey Lake and the Taylorsville district to Tejon Pass, altho there are many extensive faults, and altho on one of these there occurred a movement which caused the Inyo earthquake of 1872, yet there is no suggestion of any local movement on any of these on the morning of April 18, 1906. The intensity of the shock along this general fault-zone was about IV of the scale; but the movement was a slow, gentle swing characteristic of a heavy distant shock.

Similarly, the numerous faults which traverse California south of Tehachapi may be left out of consideration, no shock at all having been felt over the greater part of the region, and but feebly in those parts where it was felt.

There thus remain of the faults in California practically only those that fall within the zone of destruction, to merit serious consideration. The most northerly of these is the Mount St. Helena fault described by Osmont.[1] This fault has a northwest-southeast strike, and a throw of not less than 2,000 feet. It forms a well-marked and little-degraded scarp on the southwest side of the mountain and the date of its principal movement is within the Quaternary period. The projection of this fault to the northwest is not known; to the southeast it undoubtedly passes beneath the floor of Napa Valley, in the vicinity of Calistoga. Neither on the slopes of the mountain nor at Calistoga was there any evidence of abnormally high intensity, and the necessary inference is, therefore, that there was no movement on the fault at the time of the earthquake.

The southwest front of the Berkeley Hills, and the extension of the same geomorphic feature farther south, forming the southwest front of the higher Mount Hamilton Range, is with little question a fault-scarp, or series of scarps, of Quaternary date, now more or less dissected and degraded. The northern extension of the fault-zone beyond San Pablo Bay is not known. It probably contributed to the definition of the western side of the ridge between Sonoma and Petaluma, but apparently did not traverse the middle part of Santa Rosa Valley, since the study of that region by Osmont failed to reveal it.

This fault-zone is of peculiar interest from the point of view of the present discussion, since it appears to have been the seat of disturbance of the earthquake of 1868. At that time the fault-trace was marked by a crack at the surface, which was traceable for 20 miles or more along the base of the scarp slope, altho the amount of the movement was probably quite small. The trace of the fault is approximately parallel to the San Andreas Rift, and is 18 miles distant from it. As has already been suggested, this fault would seem *a priori* more susceptible to the influences which would make for renewed movement than most other faults of the region. But there is no evidence that any movement occurred upon it. The intensity showed no abnormal increase along the old fault-trace; and buildings at Berkeley, founded on rock, practically on the line of the fault, suffered little or no damage.

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[1] *Loc. cit.*

The fault which is so well exposed in the sea-cliff south of Fort Point traverses the city of San Francisco in a southeasterly direction for an unknown distance. Along the line of its probable course, Mr. Wood has noted evidence of an increase of intensity. The fault in its projection seaward probably intersects the San Andreas fault beneath the Gulf of the Farallones. It is therefore possible that there was some slight distribution of the movement along this intersecting fault.

The San Bruno fault-scarp, on the peninsula of San Francisco, south of the city, is well illustrated in Plate 15, and its structural relations are described in a paper by Andrew C. Lawson on the Geology of the San Francisco Peninsula.[1]

The base of the scarp is from 2.5 to 3 miles distant from the San Andreas Rift, and is nearly parallel to it. The fault is in two parts: a main fault with a throw of not less than 7,000 feet, which drops the Merced (Pliocene) strata against the older Franciscan rocks, and an auxiliary fault which drops a wedge of Franciscan strata between the main fault and the mass of San Bruno Mountain. The town of South San Francisco is on the lower slopes of a rocky spur of San Bruno Mountain, between the two faults, *i.e.*, it is on the dropt wedge of Franciscan rocks. In the water-saturated alluvium and sands of Merced Valley, the apparent intensity was high, ranging up to IX of the scale; but in South San Francisco, on rock foundation, it was notably lower, as appears from Mr. Crandall's report. The situation of south San Francisco, between the two faults, is such that had a movement occurred on either, the damage to structures would have been accentuated. But the fact is that the damage was not so accentuated, and there is thus no warrant for supposing that any local fault movement occurred.

One circumstance which, upon first thought, seems to contravene this conclusion, was the sudden outgush of water at one point at the base of the San Bruno scarp. This remarkable occurrence is described in another place, but may be mentioned here, for the purpose of bringing together the facts bearing on the question. The water issued, as near as can be determined, at a point on the slope immediately above the fault-trace of the auxiliary fault, in the underlying hard rocks, which are there mantled with an unknown thickness of sand, possibly 50 feet or more. The outgush of water is indicative of sudden compression of incoherent water-saturated sand, and does not necessarily imply a movement on the deeper fault. Along the line of the fault there are longitudinal depressions, and it is suggested that one of these was filled with sand, under conditions which did not permit of rapid drainage; so that the sand was saturated with water, which was expelled as the compressive wave traversed the locality.

In the region to the southwest of the San Andreas Rift in San Mateo and Santa Cruz Counties there are several faults, most of which are represented on maps Nos. 21 and 22. No evidence of movement has been detected on any of them, altho the territory has been examined quite closely; nor does their presence appear in any way to have affected the disposition of the isoseismal curves. They nearly all traverse a country occupied by rocky mountainous slopes, and have considerable variation in orientation, altho the prevailing strike is northwesterly and southeasterly. One fault, however, viz., the San Gregorio fault, crosses 2 valleys — San Gregorio Valley and Pescadero Valley — in which the intensity of the shock was abnormally high. The independence of this high apparent intensity to the fault has been pointed out in another place.

To the north of Black Mountain, on the northeast side of the San Andreas Rift, a branch fault leaves the Rift line a little south of Portola, at an angle of about 25°, and is traceable for about 8 miles on the lower northeastern flank of Black Mountain. Between this Black Mountain fault and San Andreas Rift there is enclosed a wedge of ground in which the shock was of exceptional severity. It was traversed by numerous cracks, and there are other manifestations of acute disturbance of the ground, as set forth in the more detailed section of the report. In this case it is quite possible and even probable that the movement on the main fault in the line of the Rift was distributed to some slight extent along the branch fault. It is to be noted, in this connection, that to the south of Black Mountain there is a slight curvature in the course of the main fault to the eastward. This curvature would present an exceptional obstacle to the movement of the two crustal blocks, the one on the other, greatly increase friction, and so locally intensify the shock. It may thus be that the exceptional intensity in the Black Mountain mass, and the consequent bulging of the isoseismals on either side of the fault in this vicinity, is referable to this irregularity in the plane of the fault; and that the branch fault at Portola may be a means of relief from the excessive pressure locally induced by the irregularity. On the southwest side of the San Andreas Rift, and on the other side of the bulge in the fault-trace, is the Castle Rock fault, the strike of which branches from the main fault on the Rift at an angle of about 20°. Altho this fault has not been actually traced into the line of the Rift, there can be little doubt that it is a branch from that fault-zone and it probably bears the same structural relation to it that the Black Mountain fault does, *i.e.*, it serves as a means of relief for the exceptional local pressure due to the nearby irregularity in the main fault. There is, however, no observational evidence of any movement having occurred on the Castle Rock fault on April 18, altho it lies within the region of bulging isoseismals.

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[1] U. S. Geological Survey, 15th Ann. Report.

In the Mount Hamilton Range, between Niles Canyon and Mount Hamilton, there are many faults; but none of them, so far as the information available will warrant a conclusion, appears to have affected in any way the distribution of intensity. Two of these, the Mission Peak fault, which is probably a branch from that on which cracks opened in 1868 near Haywards, and Mission Creek fault, pass close to the town of Niles. But the apparent intensity at Niles was less than on the flat alluvial tract to the west, and not greater than in the valley-land about Pleasanton and Livermore to the east; and this circumstance amounts to a proof that no movement occurred on either of these faults. A similar conclusion may be drawn with reference to the Sunol fault, from the fact that the apparent intensity at Sunol was somewhat less than at Pleasanton, altho the former is nearer the Sunol fault than is the latter. In the country between the Haywards fault and the Sunol fault there are several minor faults, but there is no indication in the distribution of intensity of movement having occurred on any of them. Similar statements are true of the fault zone extending from the vicinity of Benicia northward on the west side of the Sacramento Valley.

In the canyon of Pajaro River, below Chittenden, there is an east-west fault whereby the Tertiary rocks on the north side have been dropt against the granitic rocks of the Gavilan Range on the south. This fault crosses the San Andreas Rift, and its known extent on either side of the Rift is within the zone of high intensity referable to the movement of April 18. There are here no especial features in the distribution of apparent intensity which suggest any movement on this fault. It is possible, however, that a slight movement took place on this fault, since the steel bridge over the Pajaro River, which is about on the intersection of the two faults, was distended 3.5 feet between its end piers, as shown in plate 65B, in a way that can not be altogether satisfactorily explained by the movement on the fault along the Rift. The direction of the chief displacement of the piers was about midway between the strikes of the two faults.

In the Santa Lucia Range to the southwest of the Salinas Valley, there are several faults. The principal one runs along the northeast flank of the range on the edge of the Salinas Valley. The reasons for ascribing the high apparent intensity on the floor of the Salinas Valley to the character of the underlying formations, rather than to any disturbance on this fault, have already been stated. Farther south, a fault runs parallel with the Salinas River in that portion of its course between Templeton and Dove; but here the apparent intensity was lower than in the valley lands both to the north and to the south.

To the southwest of this is another parallel, but a longer fault, along the southwest side of the San Rafael Mountains. In the valley lands to the southwest of this, about San Luis Obispo, Edna, Arroyo Grande, and Santa Maria, the intensity rose from III to IV; but in view of the accumulation of evidence set forth in the preceding pages as to the influence exercised by alluviated bottoms upon the apparent intensity, this rise is more probably referred to the character of the ground than to proximity to this fault-line. South of Santa Maria is a region of frequent seismic disturbance, but no sharp shock of a local earthquake was felt there on April 18.

It thus appears that in the territory extending from Humboldt County to Santa Barbara County, while there are about 40 faults known to geologists who have studied the region, there is no evidence of movement on any of them except in 3 cases. One of these is a branch from the fault-zone of the San Andreas Rift — the Black Mountain fault; another is a transverse fault intersecting the Rift in Pajaro Canyon; and the third is the fault which traverses the city of San Francisco and probably intersects the San Andreas fault beneath the Gulf of the Farallones. In these cases it is possible, in the light of the evidence, that some portion of the movement on the main fault was distributed along intersecting faults.

DIRECTIONS OF VIBRATORY MOVEMENT.

GENERAL NOTE.

The data for the discussion of the directions of propagation and vibration of the earth-waves is for the most part unsatisfactory and leads only to a conviction of the complexity of the general problem of earth movement. Apart from the intrinsic complexity of the subject, there were two conditions which were adverse to the securing of exact and significant information. The first of these was the lack of provision for obtaining instrumental records of earthquake shocks thruout California. There were very few seismographs installed in the state and such as were in existence proved in large measure inadequate for the purpose for which they were intended. The second adverse condition was the hour at which the earthquake began. At its beginning most people were asleep, and the confusion incident to so rude an awakening was not conducive to sharp observation. The chief trouble, however, inheres in the intricate and confused nature of the earth movement itself. A brief statement of the different kinds of movement involved in the commotion of the earth may be of service in the formulation of clear ideas of the nature of the shock in general and of the question of direction in particular.

Usually the principal movement of the ground in an earthquake is vibratory. In the California earthquake there was, however, a mass movement in opposite directions on the two sides of the San Andreas fault. This mass movement was, as has been shown by the work of the Coast and Geodetic Survey, distributed over a wide zone on either side of the fault and diminished more or less regularly with distance from it. The movement was not vibratory except to a very limited extent; but it gave rise to the displacement of objects on the surface quite similar to that caused by the vibratory movement.

Thus, in attempting to deduce the directions of propagation and vibration of the earth-waves from the phenomena of displaced objects or persons, it is necessary to discriminate between the effects due to the mass movement and the true vibration of the ground. But this discrimination is only possible to a very limited extent, partly because the borders of the zone within which the mass movement caused the displacement of objects and persons are unknown, and partly because the two kinds of movement overlapt, conspiring to produce a single effect.

When we come to consider the earth-waves generated by the movement on the fault, probably as an effect of friction, it must be at once apparent that these waves emanated from innumerable points on a plane, one dimension of which is about 270 miles and the other probably 20 miles or more. On this plane, if we judge from the course of the fault-trace, there were at certain places inequalities which offered exceptional resistance to movement, and at these the jar was exceptionally heavy and dominated the vibrations emanating from portions of freer movement. From all parts of the fault-plane, therefore, waves of various amplitudes were propagated in all directions, and their paths intersected. The consequent interference would in part make for neutralization and in part for intensification of the vibratory movement. It is thus evident that the effects produced by the emergence of these waves at the surface, or by the propagation of those emanating from the more superficial portions of the fault along the surface, could be systematically disposed only if the following conditions obtained:

1. That the fault-plane were uniformly even or systematically uneven.
2. That the rock affected both by the rupture and by the vibrations were homogeneous thruout.
3. And that the stress which gave rise to the rupture were uniform for the entire extent of the fault.

It is fairly certain that none of these conditions actually did obtain; and we might, therefore, predict that the disposition of the effects of the shock, and particularly of the heavier portions of the shock, from which directions might be inferred, would be irregular, tho distribution of the intensity in the aggregate might be fairly symmetrical.

This conclusion has been reached on the tacit assumption that there is but one kind of earth-wave or vibratory movement. But it is highly probable on theoretical grounds, and the theory is supported by experiment, that the vibration of the earth generated at the fault resolves itself into two quite distinct waves having quite different rates of propagation and direction of vibration. One of these is the longitudinal wave, so called because the vibrations are parallel to the direction of propagation, and the other is the transverse wave in which the vibrations are normal to the direction of propagation. The rate of propagation of the longitudinal waves in highly elastic rocks is nearly double that of the transverse waves. It will thus be evident that at any locality within the zone of disturbance an object may be shaken or displaced by the emergence of the longitudinal wave at that point, and that the movement due to the emergence of the transverse wave may be superimposed upon this either before or after it has come to rest. The resultant effect will be accordingly difficult to interpret as to the direction of the vibration for either wave. When, however, the locality in question is sufficiently far removed from the fault, the interval between the emergence of the two waves may be sufficiently long to permit of the effect of the first being noted before that of the second is superimposed.

In the case of the California earthquake, the movement of the ground was complicated by the fact that both longitudinal and transverse waves were propagated in directions nearly parallel to the surface from the superficial portion of the fault, and these for many miles out from the fault might be expected to give rise to movements discordant with those due to the arrival of similar waves from the deeper portions of the fault. It would thus seem, from the considerations thus far presented, that regularity in the disposition of the effects of the shock upon which a judgment as to the direction of the vibration might be based, was about the last thing to be expected. In other words, it would seem, on *a priori* grounds, to be a hopeless task to plot upon a map of California the direction of propagation and vibration of the earth-waves. The hopelessness of the task is intensified when certain other considerations are taken into account. For example, there were secondary short surface-waves of low speed and high amplitude observed in many parts of California, which are quite different from the high-velocity waves thus far discust. These undoubtedly had an important effect in the displacement of objects and persons, and so influenced judgments as to the direction of movement. Similarly on the alluvial bottoms of the rivers the ground lurched consistently toward the stream trench, whatever the orientation of the latter might be; and the phenomena arising from such movement gave rise to judgments as to the direction of the earth-waves which were of course erroneous.

Added to all this was the general fact that those who contributed reports from various parts of the state to the general account of the earthquake in many cases based their judgment as to the direction of the shock upon the displacement of portions of structures, such as chimneys, or of objects within buildings. This kind of evidence was in most cases untrustworthy, and could lead to reliable conclusions only when treated critically and statistically so as to obtain a general result. Even the displacement of buildings themselves was no criterion of the direction of vibration of the ground except when these rested upon uniform foundations. Buildings upon poorly braced underpinning, such as are common in California, collapsed in consequence of the swaying; but the direction of the horizontal element in the collapse was more often determined by the nature of the structure than by the dominant movement of the ground. Even in cemeteries the direction of overthrow of simple shafts, circular or square in cross-section, failed to indicate the direction of the dominant movement, since within a small radius they fell to all points of the compass. The indication of the cemeteries was that the movement of the ground was very complex; the shafts were started swaying upon their pedestals, and the direction of their fall was for the most part accidental, as the rocking increased in violence due to the accumulating impulse. Treated statistically, however, the larger cemeteries afforded some indication as to the direction of the dominant movement of the ground.

In view of what has been said, it will not be surprising that the effort to interpret the reports from various parts of the state regarding the direction of movement of the ground has been unsuccessful. The reports were in general contradictory for the same locality whenever there were two or more independent observers. It was evident that most of the reports were based on evidence of the movement of the ground which had no significance in isolated instances, and a general critical review of the evidence was attempted only by a few observers. It was also evident that in many cases the effects of one movement had imprest one observer, while the effects of a different movement had attracted the attention of another. In these cases the contradiction was more apparent than real, but there was generally doubt as to the correctness of both. Even when the reports were perfectly satisfactory records of facts, the latter in many cases permitted of no safe inference as to direction of movement except that there were several movements in several directions, and that the sequence of these could not be determined.

The following report from E. G. Still of Livermore is a good example of an excellent account of the important facts bearing on the question of directions:

> The Railway Company's big 20,000-gallon water-tank fell to the north-northeast. Tombstones in one graveyard fell in many directions. Lamps swung in an oval, extending about east and west. The motion seemed to shake my bed north and south at first, then in a circular motion, then sideways and in every direction. Water spilt from full tanks, mostly on east and west sides.

There is a suggestion here of two dominant movements — a northerly and southerly, and an easterly and westerly, the former being the earlier. But Mr. Crandall, for the same territory, reports that the general direction of motion, based on the observed spilling of liquids and swaying of suspended objects, was northwest and southeast. In most cases the reports consist of a statement of opinion as to the direction of movement, without the facts upon which the opinion is based.

EFFECTS OF THE EARTHQUAKE ON HOUSES IN SAN MATEO AND BURLINGAME.

By Robert Anderson.

Immediately following the earthquake of April 18, 1906, a detailed study was made by the writer[1] of over 1,000 houses in San Mateo County. This work was carried on under the direction of Dr. J. C. Branner, of Stanford University. The houses examined included all those in the town of San Mateo and on the hills west of it in Burlingame and San Mateo Heights, as well as many in Homestead, Belmont, San Carlos, and Redwood City. Examination was made of all details that could possibly give a clue to the character of the earthquake shock, and its effects upon movable things.

San Mateo is a mile west of San Francisco Bay, and about 3 miles northeast of the San Andreas fault along which the earthquake had its origin. All the houses included in this investigation lie between 1 mile and 4 miles in a northeast direction away from the nearest points along the fault. A range of hills from 500 to 700 feet high lies between the fault and the valley bordering the bay where San Mateo and Redwood City are situated. The houses examined at Burlingame and San Mateo Heights stand on the northeast flank of this range of foot-hills. It was hoped that the directions of the streets of San Mateo, parallel and at right angles to the fault, would throw some light upon the relations of location to the center of disturbance.

CRITERIA.

The following classes of evidence were examined, with especial regard to the direction and relative force of the shock:

1. The wreckage of brick, stone, and wooden buildings, the parting of walls, and displacement of parts.
2. The cracking of foundations and the movement of houses on them.
3. The cracking, crumbling, shifting, falling, jumping, and twisting of brick chimneys above and below roofs, as well as of cement, terra-cotta, and other chimneys.
4. The cracking and falling of plaster and coatings of cement on the interior and exterior of buildings.
5. The sliding, falling, and jumping of dishes, lamps, bric-à-brac, pictures, books, potted plants, and all such loose articles.
6. The sliding, tipping, jumping, and turning of furniture, such as bureaus, tables, bookcases, beds, pianos, stoves, safes, machinery, and all other large movable articles.
7. The falling, sliding, twisting, and jumping of tanks, towers, porches, pillars, underpinnings, gate-posts, mantelpieces, derricks, etc.
8. The breaking and offsetting of pipes, bending of bolts, shifting of stove-pipes, bulging of windows with lead seams, and the raising and lowering of sliding windows.
9. The shifting of loose piles of lumber, stove, and cord wood, and various materials, and the sliding of articles on rough and smooth surfaces.
10. The swinging of hanging articles, pictures, lamps, pendulums, etc.
11. The breaking of wire connections, such as telephone, telegraph, and light wires.
12. The remaining in position of articles at liberty to fall in certain limited directions.
13. The parting of ground at base of telegraph poles and cracking of ground elsewhere.
14. The spilling and splashing of liquids.
15. The feelings, experiences, and testimony of people.

This paper gives only the general results of all the data, the more important facts alone being tabulated.

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[1] Valuable aid was received from P. C. Edwards, A. L. Motz, and A. F. Taggart, students of Stanford University.

DAMAGES.

The effects upon brick and stone buildings. — The region covered has only about 25 buildings of brick and stone. In most cases, the damage done to these structures was far more severe than to those of wood. Usually a considerable part of some of the walls crumbled away, while the rest were left standing with large and small cracks in them. The tops of walls below the roofs usually suffered most, while lines of weakness in walls, caused by the presence of windows, arches, and other apertures, gave way to cracking more readily than other parts. A few brick buildings were totally demolished, as in the case of the long, brick, railroad warehouse at San Mateo. (See plate 98A.) The whole center of the picture to the right and left of the tower was occupied by the building, of which only the foundation remains.

Some brick buildings, stoutly constructed or wedged in on business blocks among structures that acted as common supports, withstood the earthquake well, altho some portion was almost invariably damaged. The triangular gable ends of brick buildings rarely remained in place. The cracking in brick structures seldom past thru the brick themselves, but usually took place along lines of cementing. The very few stone buildings in the vicinity of San Mateo were almost shaken to pieces.

Wooden buildings. — In general, wooden structures suffered much less severely than those of brick or stone, tho the shock was felt just as heavily in them and the damage to loose articles was just as great. The buildings least damaged were small wooden houses, which were practically proof against the earthquake.

Foundations. — The effect of the earthquake on foundations was of great importance, for the foundations were responsible for much of the damage to upper parts of buildings. With reference to this point, the buildings have been divided into 3 groups — those having foundations of wood, of concrete, or of brick. Wooden foundations are of various kinds, and the group includes all houses resting directly on the ground, or on wooden sills or wooden underpinning, even if the latter are supported on brick piers; it also includes all other buildings not having foundations of hard materials, such as concrete, brick, or stone.

The foundations were examined for evidences of movements in various directions, and for the purpose of learning the relative amounts of cracking to which each was subjected. The accompanying table gives the results:

Number of houses examined, with number of houses moved, and number of foundations cracked.

Character of foundation	San Mateo.			Redwood.			Belmont, Homestead, and San Carlos.			Burlingame and San Mateo Hills.			Total.				
	Houses examined.	Houses moved.	Foundations cracked.	Houses examined.	Houses moved.	Foundations cracked.	Houses examined.	Houses moved.	Foundations cracked.	Houses examined.	Houses moved.	Foundations cracked.	Houses examined.	Houses moved.	Per cent of houses moved.	Foundations cracked.	Per cent of foundations cracked.
Wood . .	266	47	....	63	23	....	50	2	....	8	1	....	387	73	17	....	....
Concrete .	176	51	43	7	7	....	1	....	1	41	1	7	225	59	26	51	23
Brick . .	160	51	63	8	3	1	16	....	4	46	4	26	230	58	26	94	41
Total .	602	149	106	78	33	1	67	2	5	95	6	33	842	190	23	145	

The total number of houses falling into these groups is 842. Of these 23 per cent moved on their foundations. In most cases the movement was not so great as to necessitate the returning of the house to its original position, but this had often to be done, since many houses were rendered unstable. The distance moved varied from less than 0.25 inch to several inches, and in cases of special severity houses were thrown a foot or more off their underpinnings or foundations. Those on wooden foundations moved the least — 17 per cent in a total of 387 such houses. There were 225 houses on concrete foundations and 230 on foundations of brick, and in each case 26 per cent moved. Out of the total of 455 concrete and brick foundations, 32 per cent were cracked, as follows: 23 per cent of the concrete foundations were cracked, while 41 per cent of the brick foundations were cracked. Nor does this proportion fully represent the facts, for it was only in rare cases that the cracking of the concrete was of much importance; while, on the other hand, the damage to the brick foundations was often sufficient to endanger the stability of the house. The wooden foundations were rarely damaged. In cases where houses had especially heavy foundations, the damage was noticeably slighter. Heavy concrete foundations rendered structures almost immune to the shock. Not many heavy concrete bridges, for instance, were harmed. In a store that rests on the massive concrete foundation of a bridge crossing the creek in San Mateo, absolutely nothing was disturbed, altho the building overhung the creek about 7 feet. None of the many loose articles on the shelves fell, and a high top-heavy machine stood perfectly.

The falling of brick chimneys suggests the possible influence of the foundations upon these structures. Of all the chimneys on houses having wood foundations, 91 per cent fell; of those on houses with concrete foundations, 81 per cent fell; of those on houses with brick foundations, 88 per cent fell. A truer relation is given by taking merely those on the flat land at San Mateo and Redwood City, where the cases are strictly comparable. Of these the proportions in the same order are 93 per cent, 98 per cent, and 96 per cent. The disadvantage of brick foundations is further attested by the greater damage to plaster in houses built on them.

Brick chimneys. — In the region studied, the tops of 88 per cent of all the brick chimneys fell at the time of the earthquake. This proportion is for the whole region. The varying proportions in the different localities are shown in the following table:

Table showing the number of brick chimneys examined, with per cent which fell, from houses on various foundations.

Character of foundations.	San Mateo.		Redwood City.		Belmont, Homestead, and Carlos.		Burlingame and San Mateo Hills.		Total.		
	Chimneys examined.	Chimneys fell.	Chimneys examined.	Chimneys fell.	Chimneys examined.	Chimneys fell.	Chimneys examined.	Chimneys fell.	Chimneys examined.	Chimneys fell.	Per cent of chimneys fell.
Wood . .	280	257	64	63	51	44	15	11	410	375	91
Concrete .	187	165	9	8	3	3	85	55	281	231	81
Brick . .	256	242	10	9	27	24	110	88	403	363	28
Total .	723	661	83	80	81	71	210	154	1097	969	88

Besides the falling of the tops, a large proportion of the chimneys that suffered this loss, as well as a great many that did not, were injured or cracked at the base or somewhere within the house. Economically, the damage below the roof is the most serious, as it is difficult to remedy and is a menace to the safety of the building. Some chimneys crumbled away entirely. This happened most frequently to those built on the outside of the house, in which case they usually fell away from the house, doing little harm. This may be considered a point in favor of exterior flues, inasmuch as the wreckage to houses due to the chimneys falling through the roofs, as well as the difficulty of repairing interior flues, is avoided. On the other hand, the unsupported exterior chimneys show a greater tendency to fall. Ash-boxes at the bases of chimneys weakened them at these parts, and made them more liable to injury. Only 12 per cent of the tops of the brick chimneys remained standing, the reasons for their standing being generally found in the construction of the chimneys themselves. The use of cement and lime instead of simply lime mortar, accounts for the standing of many, although the use of cement did not always insure their safety. Many that stood were found not to be built up from the ground, but to rest on shelves somewhere within the house. This method of building seemed to preserve the chimney intact in the majority of cases. A few chimneys owe their preservation to their low, solid structure above the roof; many did not fall because they were well-braced, either by being inclosed in a wooden casing or a coating of cement, or by being held by iron rods clamped into the brick. A striking example of the advantage of an iron rod as support was that of a 2-story house in San Mateo. This house had a brick foundation and a slender chimney 14 feet high, supported by an iron rod. The chimney stood perfectly.

A great many chimneys that stood well above the roof were badly damaged at the base or within the house, and many were cracked above the roof and shifted a short distance horizontally. The use of cement in the mortar saved the chimneys in some instances, but a common effect of the shock on chimneys so built was to crack them somewhere and make them fall in one piece. In this way solid masses of great weight were sometimes pitched on to roofs and other parts of buildings, and the result was much greater damage to the house than was caused by chimneys built with lime mortar. Chimneys laid with lime mortar generally broke in many pieces or fell as loose bricks. The use of cement below the roof was apparently helpful, as the chief danger to that part of the chimney is from cracking rather than from falling, and the cement is much less apt to crack than the lime. The use of lime mortar above the roof is better, unless the chimney is to be boxed and braced. The construction of boxes around chimney tops, and the bracing with iron rods, are two simple and efficient preventives to the falling of chimneys of which comparatively few have made use.

Chimneys other than brick. — Many of the small houses of San Mateo County use terra-cotta thimbles or chimney pots, in place of brick chimneys. Their efficiency against earthquakes is conclusively shown by the fact that a large proportion of them stood unhurt, even when built in several sections. From 90 to 95 per cent of these chimneys past through the earthquake without harm. Galvanized-iron pipes, and stove pipes used as chimneys, were likewise unhurt in most cases. The few chimneys that were built entirely of concrete proved to be much stronger than those of brick.

Plaster. — In almost all houses with plastered walls, the plaster was cracked more or less seriously or broken off in sheets. The plaster or stucco on the outside of houses was badly damaged. In the majority of the houses, some of the walls — usually not all — were seamed with small cracks which ran in every direction and frequently in lines parallel with the laths. In other cases the cracks were wide and the walls were in large part laid bare.

The second table on page 365 gives the statistics regarding the cracking of the plaster. The first column includes the cases in which the plaster was almost unhurt or only slightly cracked. Most of these buildings did not require replastering. The second and third groups include the buildings more seriously damaged. Replastering was necessary in the second and third groups. The plaster on the ceilings of houses was much less affected than that on the side walls, and in the majority of cases was unhurt. In 2-story houses the plaster was rarely damaged as severely on the second floor as on the first floor, and in wooden houses of three stories it was often observed that the plaster on the third floor was uninjured. This restriction of the damage to the ground floor may be due to the breaking of the plaster by short, sharp movements near the ground, which were translated above into the swaying of the entire upper story. That the plaster did not crack much on ceilings was probably due to the fact that the ceilings (and the floors above) were not subjected to so much strain because they moved as one piece. Thick coatings and varieties of hard plaster seem to have been less damaged. New plaster not yet dry was not affected in the few cases observed.

Dishes, etc. — There were few houses in which something did not move or fall a noticeable distance, and yet few in which everything moved or fell. There was little regularity, even in the same house, in the amount of movement of loose objects. Innumerable instances of seemingly capricious variation could be cited. The earthquake resulted in severe damage to breakables and heavy loss of dishes and bric-à-brac. Approximate figures as to the amount of such damage are given in the table on page 365. In houses where only a few dishes fell the damage was considered slight. Those losing about half of the breakables are shown in the second column, and all of the more severe cases are placed in column 3. The percentages are at best only approximate. In the valley about 40 per cent of the houses lost slightly, and 40 per cent lost heavily, the loss in the remaining 20 per cent being intermediate. On the hills 74 per cent of the houses lost but little, and even in other cases the loss was not great. Many dishes were saved by raised borders on shelves on which they were standing. It often happened that loose articles fell from the lower shelves in pantries, etc., and remained on the topmost ones.

Windows. — It is an interesting fact that out of a total of thousands of windows in the area covered by this investigation, only a few were broken. Leaving out of account the windows of houses that were thrown down, the total number broken by the shaking or compression of the walls, or in other ways directly due to the shock, was probably not greater than 40. In several nurseries only a few panes were broken in many glass-covered hot-houses. The same general fact holds true over the whole of the San Francisco Peninsula, and in other regions affected by the earthquake that were visited by the writer. The majority of the windows that were broken were in brick buildings. That the windows were subjected to great stresses is shown by the fact that many of those made of parts joined by lead bulged considerably, and many were thrown upward with sufficient force to break their locks. In about 20 per cent of the cases where windows were raised in this way the glass was broken.

A resistant type of structure. — The data collected in this region appear to show that a house, to withstand an earthquake, should be constructed about as follows: The building should be of wood, and a wooden sill should be bolted to a deep-laid concrete foundation, the top of which should be but little above the level of the ground. It should be ceiled with wood within. Shelves for dishes should be closed in with doors, or should at least have strips along the front edges. The chimneys should be laid with cement mortar and boxed from a foot or two below the roof to the top, and the parts above the roof should be braced with iron rods. The lower the structure the less strain it will be subjected to. Such a building would be practically proof against earthquakes having an intensity below X of the Rossi-Forel scale.[1]

THE MANNER AND DIRECTION OF MOVEMENT.

Kinds of movements. — The shock of the earthquake was heavy enough to cause almost everything to move somewhat, and heavy objects were displaced as often as lighter ones. There were many cases of inconsistency in the movements, such as the displacement of heavy articles like pianos and stoves, where frail cups or vases remained in place; or such as the difference in motion exhibited by articles standing side by side. In many cases chimneys were thrown a distance of 6, 10, 15, and even 20 feet; a vase was thrown 6 feet, an accordion 4 feet, milk 8 feet. Hanging things were set in motion, liquids were spilt, and loose articles tipt over.

Upward movements in many different places were attested by the fact that sliding windows were raised several inches with such force as to break the iron latches that held them down. Possibly these windows were jerked up by their weights, which would have been thrown down with force had the houses been subjected to sharp vertical movements. In Prince Poniatowski's house, which stands on the hills at an altitude of about 500 feet, a mile from the fault-line, all the windows — over 30 in number — were so raised. It is believed that all of the windows in this case were of the kind that are balanced by weights hanging within the frame. In many places on low land the same thing occurred. In one case a baby's cot jumped up and down, breaking its castors.

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[1] Steel frames and reënforced concrete structures are also of course eminently well adapted to resist earthquake shocks of high intensity. A. C. L.

Bodies frequently assumed positions such as would have been imparted by twisting movements. This was true in the case of many houses, turrets, articles of furniture, hanging pictures, and chimneys. The apparent twists were both in the positive and the negative direction, and varied from a few degrees to 180 degrees. In the opinion of the writer, such positions were the result of a complication of movements rather than of a twisting motion. The twisted position of furniture was often ascribable to the rolling of the castors. Dishes, vases, etc., could easily change their orientation, especially if they were tipt up, as was frequently done. But the majority of articles were caused to shift their position horizontally, in one or more direct lines. A large number of houses slid on their foundations, dishes and books slid off their shelves, and but few things failed to change position.

Movement of houses. — One of the principal objects of this investigation was to find out in what direction houses moved on their foundations. Data were gathered concerning 842 wood, concrete, and brick foundations in regard to which it could be learned whether or not movement of the superstructure had taken place. Of this number 190, or 23 per cent, gave clear evidence of movement. In each case the direction and distance were tabulated. The directions are given in the following table. The distances are given in the first table on page 365.

Table showing direction of movements of houses on their foundations (total number of observations, 190).

Localities.	Group 1. Movements NW. and SW.				Group 2. Movements NE. and SE.				Group 1. Movements N. and S.		Movements in directions of Groups 1 and 2 combined.				
	NW.	W.	SW.	SW. and NW.	NE.	E.	SE.	NE. and SE.	S.	N.	NW. and NE.	W. and E.	SW. and SE.	SW. and NE.	NW. and SE.
San Mateo	25	23	40	18	8	....	10	2	4	4	....	2	3	5	5
Redwood	6	8	1	....	1	10	5	....	1	2	....	....	....	....	....
Belmont, Homestead and San Carlos	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....
Burlingame and San Mateo Hills	....	....	2	1	....	....	....	....	....	....	2	....	....	....	....
Totals	31	31	41	19	9	10	15	2	5	6	2	2	3	5	5
Group totals	125				36				8		17				
Group per cents	65				19				6		9				

Moved either SW. or NE., or in both directions, 31 per cent of total; moved either NW. or SE., or in both directions, 27 per cent of total.

The majority of houses that shifted moved southwest and northwest, or combinations of these directions. The west movements tabulated in practically every case were a combination of movement of the house over the edge of the foundation to the northwest and southwest equal distances, so that the effect was the same as from a single movement west. It was not known whether there had been a single shift west, or two at right angles southwest and northwest. The author inclines to the belief that there were two main movements causing houses to shift southwest and northwest, rather than one in an east and west line, inasmuch as so many of the movements were simply southwest or northwest, or not directly west. The movements tabulated in the southwest and northwest column are those cases in which both movements affected the house, one predominating over the other. Grouping together all movements recorded as northwest and southwest and west, it is shown that 65.5 per cent of all the houses moving shifted in these directions. The second group of the table includes all movement in directions opposite to those of group 1 — that is northeast, east, and southeast. These make up 19 per cent more of the total. In the third group are included all those moving back and forth in the directions of groups 1 and 2, or partly in one main direction and partly opposite to the other main direction. These comprize 9 per cent. If, then, as the writer supposes, the west and east directions may be eliminated by being separated into their components, there will be 93.5 per cent of the total number that moved northwest, southwest, northeast, and southeast.

Movement of chimneys. — The great majority of chimneys in the region under discussion are of brick. They are of many different shapes and sizes, in different positions on the roofs, of various materials, and are affected by structural variations and by age. They could not be expected to show perfect consistency in the direction of fall, but statistics were gathered in order to find out the tendency of the majority and their value as indicators of direction and intensity.

In the following table the brick chimneys are grouped according to whether they fell in the direction of the slope of the roof on which they stood, obliquely, or at right angles to this; directly opposite to this, up the roof; or according to whether they jumped. Those not falling form another group, of which a few shifted horizontally. The majority of streets on which the houses enumerated in this paper are situated, run in northwest and southeast, and southwest and northeast directions, so that the slopes of roofs are generally in those directions. More slope northwest and southeast than southwest and northeast. These directions of roof-slope make themselves apparent in the table, inasmuch as the slope of the roof exerts a marked control over the direction in which a chimney falls.

Table showing the directions in which brick chimneys moved.

Chimneys which fell down the roof, i.e. with the roof-slope.				Chimneys which fell in a direction oblique or opposite to the roof-slope, and those shifting or jumping.							Total movement in all directions.		
Direction.	Number fell.	Per cent by directions.		Number falling obliquely to roof.	Number falling opposite to roof.	Number jumped.	Number shifted.	Total.	Per cent by directions.		Total number chimneys moved.	Per cent moved by directions.	
NW.	175	31	53	8	4	10	5	27	10	22	202	24	42
SW.	121	22		15	7	8	1	31	12		152	18	
NE.	102	18	42	19	3	4	...	26	10	19	128	15	34
SE.	133	24		14	7	2	2	25	9		158	19	
NNW.	1	0.25	1	15	...	1	...	16	6	19	17	2	7
WNW.	1	0.25		15	...	...	...	15	6		16	2	
WSW.	...	...		6	...	1	...	6	2		7	1	
SSW.	1	0.25		13	...	...	...	13	5		14	2	
SSE.	...	...		12	...	...	...	12	4.5	15.5	12	1	5
ESE.	...	...		10	...	...	...	10	3		10	1	
ENE.	...	...		8	1	...	...	9	3		9	1	
NNE.	1	0.25		12	1	...	...	12	5		14	2	
W.	5	1	2	21	1	1	...	23	9	13	28	3	5
E.	7	1		10	...	1	1	12	4		19	2	
N.	5	1	2	8	...	1	...	9	3	11.5	14	2	6
S.	8	1		19	...	2	...	22	8.5		30	4	
Total	[1]560			[2]205	[3]25	[4]31	[5]9	270					
Southwest-northeast, 40 p. ct. Northwest-southeast, 55 p. ct.				Northwest-southeast, 19 p. ct. Southwest-northeast, 22 p. ct.							Northwest-southeast, 43 p. ct. Southwest-northeast 33 p. ct.		

[1] 60 per cent of all that fell.
[2] 22 per cent of all that fell.
[3] 3 per cent of all that fell.
[4] 3 per cent of all that fell.
[5] 7 per cent of all that did not fall.

Fell in known directions	821	
Caved away and fell in doubtful directions	101	
Total fell		922
Shifted		9
Stood without falling		118
Total number of chimneys		1049

It will be seen from the preceding table that out of a total of 922 brick-chimneys that fell, 60 per cent went down the roof, while only 3 per cent fell in the opposite direction; 22 per cent fell obliquely, and 3 per cent with a leap apparently regardless of the roof. The predominance of the northwest and southwest directions, however, does not seem to be wholly due to the roof-slope. The table shows that in each division the northwest-southeast and northeast-southwest directions of movement are in the majority, even tho the chimneys have fallen in a direction contrary to the slope of the roof. The evidence here is not of the best, but there certainly seems to be a tendency toward motion in the same directions as those dominant in the case of the houses themselves. It may be supposed that chimneys fell in those directions owing to the movement of the house, but the majority of chimneys falling came from houses that were not dislocated.

The evidence of the chimneys falling obliquely, up the roof, shifting, and jumping was the best, since they moved without regard or in opposition to structural influence. Among these much the largest number of movements in any two directions were northwest and southwest, and the next largest number just opposite. The northwest-southeast and southwest-northeast movements, then, were in the majority, making a total of 41 per cent, while a majority of those remaining moved in directions intermediate.

Movement of dishes, books, etc. — Such loose articles as books, dishes, bric-à-brac, and lamps are, as a rule, free to fall or slide as they will, but in this region, especially in the town of San Mateo, the shelves on which many of them stood faced northwest, southwest, northeast, and southeast. The possible directions for falling in such cases were limited and this detracts somewhat from the value of the figures in the table.

Table showing percentage of directions in which dishes moved.

Direction.	Per cent moved, by directions.			Direction.	Per cent moved, by directions.		
NW.	22	49	89	W.	4	7	11
SW.	27			E.	3		
NE.	20	40		N.	1.5	4	
SE.	20			S.	2.5		

SW. to NE., 47 per cent; NW. to SE., 42 per cent.

Of objects overthrown, 89 per cent fell in one of these four directions. Tho many of the movements were determined solely by the direction in which the shelves faced, still the small number of movements in intermediate directions favors the idea that northwest and southwest and opposite movements predominate, for many of the cases recorded were of articles free to fall in any way whatsoever, and others were of articles that slid some distance along shelves without falling off. The east and west movements were more important than those north and south, showing a tendency in that way.

As to the cases in which dishes remained in position without appreciable shift on shelves facing in the four main directions of movement, the southwest-facing shelves were most of them left empty, and there was a much greater number of cases in which dishes remained stationary when it seemed natural for them to fall northwest, northeast, or southeast.

The case of a town library is especially worthy of mention: of books facing southeast, none fell; of those facing northwest, a few fell; of those facing southwest, all fell.

Movement of furniture, etc. — These data include facts concerning the direction of movement of pianos, stoves, tables, bookcases, beds, bureaus, counters, cases, mantelpieces, safes, deposits of merchandise, and the like. These were generally free to move in all or most directions. The way in which the furniture was moved was learned at every house, and the results tabulated by regarding every direction of movement in any one house as a unit. Each unit, or case of movement, therefore, usually represents several individual movements.

Table giving data in regard to the moving of furniture.

Directions.	Percentage of cases in which furniture, etc., moved.	Number of cases in which articles, such as pianos, stoves etc., moved.	Directions.	Percentage of cases in which furniture, etc., moved.	Number of cases in which articles, such as pianos, stoves, etc., moved.
NW.	19	14	SSE.	2	. .
SW.	31	6	ESE.	0.3	. .
NE.	18	4	ENE.	0.3	. .
SE.	11	6	NNE.	0.3	. .
NNW.	1.3	. .	W.	5	5
WNW.	1.3	2	E.	3	2
WSW.	2.0	. .	N.	2	2
SSW.	1.3	. .	S.	3	3

Here again the movements in northwest, southeast, southwest, and northeast directions far outnumbered all others. The total movements in these directions is 79 per cent. There were many cases of movements in directions slightly oblique to these, but tending the same way, which, if included, would swell the total. The southwest direction was much more frequent than the northwest, and the movements along southwest-northeast lines were much in excess of those at right angles. The west and east shiftings were more frequent than those to the north and south. The pieces of furniture moved in various ways, tipping over, sliding, and jumping. The movements were often back and forth. There is an apparently authentic case of a china closet tipping to the northwest, resting at an angle of about 60° against an obstruction, and tipping back to its original position. The number of heavy pianos, stoves, and safes which were moved is given in the preceding table. Sixty-six per cent of them were moved northwest and southeast and southwest and northeast. The evidence is especially good in such cases as the sliding of cash registers and scales on smooth counters, which in several instances went northwest, southwest, and southeast. The ornamental top of a soda fountain, balanced and free to fall any way, fell toward the southwest.

Experiences and testimony of people. — An earthquake comes and goes so suddenly and unexpectedly, and there are so many things to think about, even when one is able to formulate any thoughts whatever, that the description by people of the manner in which they felt the shock is apt to be only fragmental at best. It is the almost universal testimony in the San Mateo region that the first shock was followed by a lull, and that this was followed by a renewal of the motion in a different direction. Many state that the shock following the momentary lull was the heavier of the two. As to which of the two movements along lines northwest-southeast and southwest-northeast came first, little evidence has been forthcoming. Persons who agreed in regard to there being two successive directions of vibration differed as to which preceded. There were two cases of the spilling of liquids noticed by persons, and in both the statement was made that the liquid splasht toward the northwest at the first shock. In one of these cases the northwest splash was followed by one toward the southeast. A lady who was awake when the shock came said that things on the southeast side of the room began falling first. A jeweler declared that he was satisfied, from the movement of his pendulums, that the main shock was southwest and northeast. Two people were thrown out of bed in the same house, one of them being thrown northeast, the other southwest. One of these, after getting up, was thrown southeast from a standing position.

Splashing of liquids. — A form of evidence that could not be influenced by artificial position of any kind is that of the splashing of liquids. It is, however, evidence that is difficult to get at, partly because the signs of direction are so transient, and partly because even when they remain long enough to be seen, they are apt to be either carelessly or not at all observed. The 30 cases of spilling that were considered trustworthy and were recorded point to movements northwest-southeast and southwest-northeast.

Table showing directions in which liquids spilt.

Direction.	No. of cases of spilling.	Per cent, by directions.	
NW.	6	20	43
SW.	6	20	
Both NW.-SW.	1	3	
NE.	4	14	14
SE.	....	....	
Both NW.-SE.	4	14	31
Both SW.-NE.	5	17	
ENE.	1	3	12
W.	1	3	
Both E. and W.	1	3	
Both ESE. and WNW.	1	3	
Total	30		

SW. or NE., or both SW. and NE., 51 p. ct.; NW., or both NW. and SE., 34 p. ct.

In 20 per cent of the cases the liquid spilt northwest; in 20 per cent southwest; and in 3 per cent in both directions, making a total in these two ways of 43 per cent. Fourteen per cent spilt northeast, and 31 per cent northwest-southeast and southwest-northeast, in combination. This makes a total of 88 per cent in which spilling took place along the same lines in which movement in all previous cases predominated. The rest of the cases of liquids spilling tended the same way, none having gone north or south. The water in a reservoir was observed by one man at the time of the shock. He said the water seemed to move in waves toward the northeast, and that it splasht high on the northeast side of the reservoir. Others declared that waters were calmed by the quake. Tanks of water were repeatedly either wholly or partly emptied by the splashing of the contents. One lady states that her goldfish were thrown out of a little pool with the water, toward the east-northeast and west-northwest.

Movement of various other bodies. — This paragraph includes all important items of evidence that have not found a place in previous sections. It covers cases of falling, leaping, and sliding of towers, tanks, porches, pillars, underpinnings, gate-posts, arches, roofs, and the pulling apart of walls and partitions, besides the movement of many smaller articles. The evidence in most of these cases is especially good. For instance, a heavy marble slab on a counter slid lengthwise toward the northwest. A derrick which was leaning northeast was thrown toward the southwest. The following are the percentages in over 50 such cases: southwest, 35 per cent; northwest, 24 per cent; southeast, 17 per cent; northeast, 11 per cent; a total of 87 per cent for these 4 directions, while the other 4 directions, north, south, east, and west, total only 13 per cent of the movements. This is more evidence tending to the same conclusion as before; namely, that the southwest and northwest movements, and their opposite directions, far outnumber all others. In general, things that are thrown or that fall or slide freely furnish the best criteria for judgment as to the direction. The above list is largely made up of data of this kind. The cases of pulling apart of walls included are very few, for in the majority of instances in which parting of walls occurs the action is dependent on too many other factors.

Predominance of northwest and southwest movements. — It has been shown that the movements northwest and southwest, and those opposite, greatly exceed in number those in all other directions; and there is no question as to the predominance of the first two over those opposite to them in almost every case. It is clearest in the movement on foundations and the splashing of liquids. Evidence in regard to relative amounts of movement in the first-mentioned directions and in those opposite seems to be best in the case of foundations, since loose articles may often have been thrown in the direction of an earthquake thrust, while houses moved opposite to it. The supposition is that houses usually shifted opposite to the thrust. Furthermore, it must be borne in mind that the contents of a building may be influenced by the movement of the building, rather than by the direct earthquake thrust itself, and thus give results pointing in the opposite direction.

Cause of shifting. — From the fact that northwest and southwest displacements were of most frequent occurrence, it seems likely that the main earthquake movements were southeast and northeast.

The fault which is believed to have caused the earthquake runs in a direction about N. 40° W., and passes within 3 miles of San Mateo. It will be noted that the dominant directions of movement were parallel and at right angles to the fault-line.

Evidence appears to show that in any one direction there was a succession of thrusts. In one instance, a bureau was jerked by successive small movements a distance of 6 feet toward the northwest. The course of such moving objects can often be traced by the marks left in dust. Some objects that were moved had returned to their original position when the end of the shock came.

Relative intensity of the main movement. — Considering only the northeast-southwest directions and those at right angles to them, we find that of all the houses that moved on their foundations, 31 per cent shifted southwest and northeast, and 27 per cent northwest and southeast. (See table on page 359.)

Of the chimneys that fell obliquely or upward with reference to the slope of the roof or that jumped or shifted, which gave the most trustworthy evidence in cases of falling chimneys, 22 per cent moved southwest and northeast, and 19 per cent northwest and southeast. The figures for all the chimneys give the predominance to movements in the northwest and southeast directions, but this fact is not significant, since the majority of roofs sloped in those directions.

Among the cases of liquids spilt, the southwest-northeast movement was greatly in excess of that northwest and southeast, 51 per cent of the total spilling in the former ways, and 34 per cent in the latter.

In addition to the evidence of the figures in other tables, that given in the table on page 361 may be cited. Forty-seven per cent of the dishes and similar articles went southwest and northeast, while 42 per cent went northwest and southeast. The same fact is indicated by the dishes that faced in these directions and did not fall. Fifty-eight per cent of the cases in which dishes remained standing on the shelves, when they were at liberty to fall in one or more of these ways, were cases in which they failed to fall northwest or southeast. According to the table on page 362, in 49 per cent of the cases of furniture movement the direction taken was either southwest or northeast, or both; whereas it was northwest or southeast in only 30 per cent of such cases.

The following table enumerates the cases in which houses moved a distance of more than 0.25 inch on their foundations; in other words, the worst cases of the kind. It gives the sum of the distances moved in each direction.

Among the most serious shifts, those to the southwest predominate slightly in number and distance over the northwest ones, but owing to the excess of southeast movements over those to the northeast the percentages for the combined opposite movements are just the same — 37 per cent in each case. Numerous houses shifted both southwest and northwest, but different distances each way. In exactly half of the cases the movement southwest was greater, and in the other half that of the northwest movement was in excess, while the average distance moved either way was the same.

Number of cases in which houses moved measurable distances on their foundations in different directions, and average distance moved.

Direction.	Number of houses moved.	Average distance moved (inches).	Total moved and percentage by direction.		Average distance moved (inches).
				Per cent of total.	
NW.	31	1.19	84	69	1.15
SW.	39	1.05			
W.	14	1.36			
NE.	6	1.91	29	24	1.39
SE.	14	1.29			
E.	9	1.22			
N.	4	2.37	9	7	1.50
S.	5	.80			
Total . .	122	1.24			

Southwest-northeast, 45=37 p. ct. of total; northwest-southeast, 45=37 p. ct. of total. The entire number moved in first three and opposite directions was 113, or 93 p. ct. of total.

INTENSITIES.

The houses covered by this study may be grouped in three divisions, according to locality: those on the hills at Burlingame and San Mateo heights; those at Belmont, Homestead, and San Carlos, which are partly on the level valley land and partly on the low hills; and those at San Mateo and Redwood City, on the valley-floor. The data indicate strongly that the intensity of the shock was less on the hills than on the flat, in spite of the fact that the houses on the hills were nearer the fault-line. In fact, several houses on the rock-formed hills very near the earthquake fracture did not give evidence of any greater intensity than those at San Mateo.

The Buri-Buri Ridge, as the hills are called, is composed of an old and very much compacted series of sedimentary rocks, sandstone, shale and jasper, and of serpentines. Moreover, they are not deeply covered with soil, so that they form a strong foundation for the houses.

The percentage of houses that moved on their foundations on the hills was 6 per cent; and at Belmont, etc., 3 per cent moved, as against 27 per cent at San Mateo and Redwood City. This is shown in the table on page 355. Among the very few houses that shifted on the hills and in the Belmont region, only 4 or 5 moved an appreciable distance, while in a majority of cases in the valley the movement was considerable.

From the figures given in the table on p. 356 it appears that of the chimneys, 73 per cent fell on the hills, 88 per cent in the intermediate settlements, and 92 per cent in the valley. The intensity of the shock, as shown by the amounts of falling of dishes and cracking of plaster, was greater in the flat country. The following table gives the percentage in these cases. Of course the classification of the damage is very arbitrary and the figures at best are but indicative. Of cases recorded in which furniture failed to move appreciably in houses, 90 per cent were on the hills.

Degrees of damage to plaster and household articles on hills and low lands.

AMOUNT OF DAMAGE.	SAN MATEO AND REDWOOD.			BELMONT HILLS, ETC.		
	Slight.	Medium.	Great.	Slight.	Medium.	Great.
Percentage in cases of cracking of plaster	40	30	30	79	11	10
Percentage in cases of falling of dishes, etc., in varying amounts	40	20	40	74.3	23.3	2.3

The testimony is good in all cases that structures on the hills suffered less severely from the earthquake than those on the plain. If a large amount of similar data could be collected on the low, alluvial, often marshy, flat land bordering the bay, it would probably be shown that the movement there was still more intense. Houses, however, are not frequent there. In low bottom-land there were indications of great intensity, and especially in the case of ground artificially filled in. A good example was given by the electric railroad track a few miles north of San Mateo, shown in plate 97c, D. It was built over the low land on a heavy, but loose, embankment of earth and stone. At one place this roadbed was shaken apart between the rails, and a crack from 1 to 2 feet wide and extending down many feet, nearly if not quite to the level of the valley, was formed in it for a distance of over 1,000 feet. It ran northwest and southeast, parallel with the road, and thruout that stretch not one of the heavy steel rails was left unbent. One 30-foot rail that was examined had been bent 2 feet horizontally and 10 inches vertically. Such wrecking of railroad tracks occurred wherever the underlying foundation was loose, but the stretches of track on solid ground were not affected. The low, muddy land along San Francisco Bay, east of San Mateo, was seamed with cracks by the earthquake.

CONCLUSION.

The following are the main conclusions arrived at in the course of the work:

1. It is evident that much of the damage to houses, as well as to their contents, could be avoided by judicious construction. The disadvantages of certain classes of structure should be acknowledged, and search made for more successful styles. Houses practically earthquake-proof can be built easily and cheaply.

2. The dominant directions taken by moving bodies during the course of the earthquake shock were southwest and northwest, with movements northeast and southeast only second in number. There appear to have been felt in this region two main thrusts or sets of movements that emanated from the fault-line in southeast and northeast directions.

3. The shock was less heavily felt on the hills than on the level land. The lower slopes were affected in an intermediate degree. The difference in the two extremes was probably almost as much as one degree of intensity in an earthquake table of 10 units.

DIRECTIONS IN THE TOMALES-BOLINAS DISTRICT.

By G. K. Gilbert.

The greater number of my notes as to direction of motion pertain to the shifting of houses which left their foundations. Most of the houses in this district which were thus shifted stood on light, vertical, wooden piers or props, and fell from their props in shifting. The direction of falling was so frequently downhill as to show that the slope of the ground was an important factor, and this fact leads me to give little weight to data of this character. There were, however, a few houses which, resting upon flat, unyielding foundations, were shifted horizontally upon these, and their evidence is of greater value. I think also that some weight should be given to the dominant direction in which houses of a group were thrown from their supports.

Other data as to direction are found in the falling of men and animals, and these seem to me of value wherever a dominant direction affected a group of individuals. The direction of fall of a single individual might readily be conditioned by muscular reactions, and thus give little evidence as to the direction of the strongest tremor.

I am led to question evidence from the shifting of furniture and the throwing down of objects on shelves, because in every instance the direction of vibration of a building appeared to be controlled partly by its structure. In view of these considerations, I regard the greater number of my observations on direction as of little significance, and do not report them.

The clearest data as to direction are at Inverness. While there was much variety in the direction of motion of houses at that locality, it was quite clear that the dominant direction was westward. This also was the direction toward which 4 out of 5 water-tanks were shifted, and it was the direction toward which the mud on the bottom of Tomales Bay was moved. The locality is within less than 1 mile of the fault-trace and is on the southwest side.

At Point Reyes Station, situated 0.25 mile northeast of the fault-trace, the dominant direction of shifting was southward, and an exceptionally definite record was made by the school-house, which rested on a firm, flat foundation and was slid toward the south.

At Olema, 2 miles southeast of Point Reyes Station and similarly related to the fault-trace, the dominant direction of motion was southwest, or toward the fault, the best single instance being that of a pool of water which spilt in that direction.

At Dipsea Inn, 0.66 mile northeast of the fault, a pier running northeast from the spit was wracked toward its outer end. A line of telephone poles crossing the lagoon from the end of the pier was slanted in the same northeast direction. In the Inn objects were thrown southwest, and of three cottages injured two were shifted or wracked to the southwest. On the mainland nearby a part of Mr. Morse's pier was wracked to the southwest. Collectively these facts indicate a dominant vibration to and from a northeast direction.

At Willow Camp, close to the east angle of Bolinas Lagoon and about a mile northeast of the fault, several houses moved short distances toward the southeast.

These various directions are platted in fig. 65.

DIRECTIONS INDICATED BY MONUMENTS IN CEMETERIES.

Prof. F. Omori attempted to determine the directions of the earth's vibrations by a statistical study of the thrown monuments in the cemeteries south of San Francisco. The results of his investigations are shown graphically in fig. 66, in which it appears that the greater number of monuments were thrown in the quadrant between northeast and southeast. The mean direction of overthrow is N. 76° E., which is regarded as the direction toward which the greatest horizontal displacement took place due to vibration. Other observations on the directions of the vibratory movement may be found in Professor Omori's paper.[1]

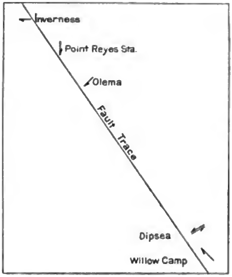

FIG. 65. — Directions of earthquake motion.

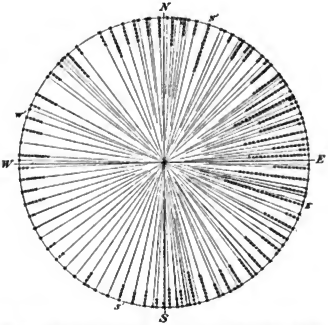

FIG. 66. — Statistical representation of the directions of fall of monuments in the cemeteries south of San Francisco. Each x represents a monument which fell in the direction indicated by the radius on which the x is placed. After Omori.

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[1] Preliminary note on the cause of the San Francisco earthquake of April 18, 1906. Bull. Imp E. I. C., Vol. 1, No. 1.

MARINE PHENOMENA.

The effect of the earth movement on the sea-level. — In earthquakes along coastal regions the waters of the ocean are usually affected, particularly if there be a displacement of the sea-bottom. If the displacement has a considerable vertical component, so that one portion of the sea-bottom is dropt relatively to an adjacent portion, the ensuing displacement of the prism of water over the region affected will generate a periodic wave, which will cause the water along the coast to rise and fall with more or less disastrous results. If the dropt portion of the sea-bottom is on the landward side of the fault upon which the displacement occurs, the wave will be greater for the same amount of displacement than if the drop is on the seaward side. If, however, the vertical component of the displacement is quite small, and the movement is chiefly horizontal, as in the case of the fault of April 18, 1906, the sea-wave will be correspondingly insignificant.

The bottom of the Gulf of the Farallones, which was traversed by the fault from Bolinas Lagoon to Mussel Rock, comprizes the inner shallower portion of what is known as the 100-fathom plateau off the coast of California. This plateau stretches seaward, with an average breadth of 22 miles, immediately off the short line of coast from Pigeon Point, in latitude 37° 11′, to the mouth of Russian River, in 38° 26′, a distance of about 80 geographic miles. The area of this part of the plateau is about 2,500 square miles, which includes the area of the Gulf of the Farallones, about 1,200 square miles. On it lie the Southeast Farallones, the North Farallones, Noonday Rock, and the Cordell Bank, having a northwest and southeast bearing thru 30 geographic miles. The line projected southeastward strikes Pigeon Point. (See map No. 4.) The summits of the Farallones rise as much as 340 feet above the sea; Noonday Rock has 3 fathoms of water over it, and the Cordell Bank has 19 fathoms. Inside of these islets there is a very uniform bottom of sand, with a gradually decreasing depth of water toward the shore. Outside of the islets the grade of the bottom rapidly increases. The 100-fathom line reaches 5 miles to the southwest of the Southeast Farallones; thence it is 10 miles to 500 fathoms and 29 miles to 1,728 fathoms.

There is no means of directly ascertaining the amount of the vertical component of the fault of April 18 for those portions of the fault-trace which lie on the sea-bottom across the Gulf of the Farallones or in the region to the northward. But where it traverses the land to the south of Mussel Rock, there is no evidence of vertical displacement; and to the north of Bolinas Bay, while there is evidence of an uplift on the west side of the fault, that uplift is slight, not exceeding 1 or 2 feet. The absence of a periodic wave at the Golden Gate indicates that the vertical displacement on that segment of the fault which crosses the Gulf of the Farallones, if there was any, was very small. While there was no periodic wave of the oceanic water generated by the horizontal displacement of the sea-bottom, there was an interesting disturbance of the level of the sea, shown by the tidal gage near Fort Point on the south side of the Golden Gate, which is probably to be classed with the secondary phenomena arising from the displacement.

The tidal gage yields a record known as a marigram, upon which is chronologically indicated the rise and fall of the water in the Golden Gate with the incoming and outgoing of the tide. The record is said to be sensitive to the impact of waves breaking upon the bar outside the heads distant some miles from the gage. It is also sensitive to the conflicting volumes of water from the north and south parts of the Bay, when these are striving for mastery on the fading tide. Former submarine earthquakes in distant parts of the Pacific have generated waves which have been recorded on the marigram at the Golden Gate. The marigram near Fort Point, for April 18, 1906, shows (fig. 67) a depression of the water-level in the Golden Gate at the time of the earthquake, or rather a little subsequent to that event. The amount of the depression was slightly in excess of 4 inches. The marigram shows a blurring of the pencil mark from the direct action of the earthquake agitation, and this bearing serves to give approximately the time of the shock. It shows that the running clock of the gage was probably too slow, and that the depression of the water-surface did not begin instantaneously, but followed after an interval which may have been from 9 to 10 minutes. Before the shock the gage had had a small vertical movement, ascribed by the officers of the Coast and Geodetic Survey to an imperfect oscillation across the Golden Gate. This minor vertical movement continued during the drop in the level of the water after the shock. The time for the lowering of the water was 9 minutes, as near as can be read from the marigram. It immediately began to recover, and the record shows that the water level rose without minor oscillations, to the normal level within 7 minutes, the total interruption in the normal marigram curve due to this depression being 16 minutes. After full recovery to normal level, the depression was not followed by a complementary rise of the water-surface, and in this sense the movement was not periodic. The minor oscillations referred to above ceased when the maximum depression was reached, and do not appear in their characteristic forms on the marigram curve for some hours after. They were replaced, however, after 6 o'clock, by 2 or 3 oscillations having a period of about 40 to 45 minutes and an amplitude of 1 to 2 inches. These probably correspond to oscillations in San Francisco Bay.

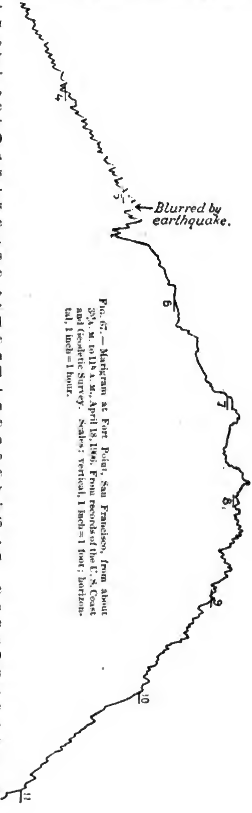

FIG. 67. — Marigram at Fort Point, San Francisco, from about 3½ A. M. to 11^h A. M., April 18, 1906. From records of the U. S. Coast and Geodetic Survey. Scales: vertical, 1 inch = 1 foot; horizontal, 1 inch = 1 hour.

The Tidal Division of the Coast and Geodetic Survey very kindly computed the time which would be required for a wave generated at the fault-line on the bottom of the Gulf to reach Fort Point, and found that it would require 9 minutes, on the assumption that Fort Point is 6 statute miles distant from the fault-trace in a direction normal to it. The position of the gage is, however, 1.3 miles distant from Fort Point within the Golden Gate, so that the time necessary for the wave to reach the gage would be somewhat longer. Now the time at which the gage began to fall is between 9 and 10 minutes after the first interruption and blurring of the record by the shock itself, and this coincidence in time suggests that the fall in the water near Fort Point was due to a negative oscillation generated at the line of the fault. The effect produced would have been brought about had there been a slight drop of the sea-bottom on the outer side of the fault. But there is independent evidence, to the north and south of this particular segment of the fault, that there was no drop on the west side, so that this explanation can not very well be entertained.[1] It is also possible that the effect observed might have been brought about by a slight expansion of the confines of the Gulf of the Farallones, due to the differential movement along the fault, but this would not explain the coincidence in time. The period of the east-west oscillation of the waters in the Bay of San Francisco, between West Berkeley and Fort Point, has also been computed by the Tidal Division of the Coast and Geodetic Survey to be about 40 minutes. This agrees fairly well with the two or three oscillations recorded by the gage after 6 o'clock, and indicates that the drop of the water-surface outside of the Golden Gate generated an east and west oscillation in the Bay of San Francisco.

Tidal observations conducted at Fort Point for a period of 1 year from the date of the earthquake indicate that there was no change of the relative altitude of sea and land at that point, as compared with the conditions prevailing during the 3 years preceding. A review of the observations for the past 9 years, by the Coast and Geodetic Survey, reveals, however, the interesting fact that in that period of time there has been an apparent subsidence of the coast at that point of 4.8 inches, practically all of this having been accomplished in the first 6 years of this period. There has been no movement in the last 3 years. (April 18, 1907.) The only other tidal gage maintained on the coast of California is that at San Diego, and the marigram obtained there shows no abnormal movement of the surface of the sea referable to the earthquake.

The only other report indicating that the level of the ocean was affected along the coast is by W. W. Fairbanks, of Point Arena, who says: "I have endeavored to learn of any unusual action of water along the sea-coast, and can relate but one instance of anything approaching the character of a tidal wave. On the day of the shock I traveled by wheel and on foot from Albion to Point Arena, 25 miles. At the mouth of Navarro River, at 8 o'clock on the morning of the 18th, I learned from reliable sources that a section of about 10 acres of low, flat land about the mouth of this river was entirely submerged for some minutes immediately after the shock."

The shock felt by ships. — Information regarding the perception of the shock on ships at sea or in harbors has been collected by Prof. George Davidson, and the following notes are chiefly the result of his inquiries:

The U. S. T. S. *Pensacola*, moored to the pier at the U. S. Naval Training Station, Yerba Buena Island, San Francisco Bay, felt the shock on the morning of April 18, 1906. Surgeon L. W. Curtis reports that while in bed on the *Pensacola* he felt a vibratory shock lasting about 30 seconds, with one heavy jar about the middle period of the shock. A gentle rumbling sound coincided with the shock. The phenomenon closely resembled vibrations which are at times set up in the ship's hull on starting the dynamo, and it was mistaken for that, tho much more active and exaggerated than ever before observed. The vibration shook down some loosely piled books and papers from a table.

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[1] This explanation is, however, advocated by Prof. H. F. Reid. In a note received while these pages are in proof he says: "If a depression occurred on the western side of the fault-line, extending for some distance to the westward, it would start a wave of depression towards the Golden Gate which would take 9 minutes to reach Fort Point and this is just about the time recorded by the gage. The time necessary for the recovery to normal level would depend upon the extent of the area depressed. If this were a narrow block, a wave of elevation would follow quickly upon the wave of depression and we should have a rapid elevation of the tide-gage above its normal position. As no such wave appeared and recovery was very gradual we must suppose that the deprest area extends for some distance to the westward, so that the recovery was slow. This is the only explanation so far offered, that would produce the effects observed."

The pilot-boat *Gracie S.* was lying in 18 fathoms of water near the lightship off the San Francisco Bar. She was suddenly struck by a seaquake which caused her to quiver as if the chain were running out of the hawser pipe. When the pilot boarded the German Cosmos steamship *Nyada*, the captain reported that his vessel had been shaken as if she had struck on rocks. The pilot-boat *Pathfinder* was lying in the vicinity, in 20 fathoms, and reported the same effect.

The steam collier *Wellington*, inward bound, between Fort Point and Point Diablo, in 50 or 60 fathoms, reported that the vessel was struck as if she were upon rocks. (Personal report of Captain Hayes, of the Board of Pilots.)

The steamer *Alliance*, off Cape Mendocino, reported by Mr. H. H. Buhne, of Eureka: The captain said she was struck a hard blow, as if she had run on a rock at full speed; time, 5^h 11^m. Mr. Buhne states that all ships in the harbor at Eureka felt the quake, but in South Bay it was heaviest. One vessel was hurled against the wharf time and again, throwing down piles of lumber and shingles.

The schooner *John A. Campbell* felt the shock at sea, off Point Reyes. The following is a memorandum of the event by Capt. C. J. S. Svenson: "Ship's local apparent time April 18, 1906, 5^h 15^m A. M. Lat. 38° 00′ N. Long. 126° 06′ W.; 145 miles true west of Point Reyes. Weather fine; sky clear; wind fresh from north-northwest; sea moderate; ship's course southeast; speed 7 miles per hour. The shock felt as if the vessel struck lightly forward and then appeared to drag over soft ground, and when aft a slight tremor was felt; the whole lasting only a few seconds." The depth of water in the vicinity of the ship's position is 2,400 fathoms.

The steamship *National City* was approximately in lat. 38° 24′ N. and long. 123° 57′ W; 29 geographical miles distant from the nearest point on shore and about 31 miles from the fault-trace along the valley of the Gualala River. The vessel felt the shock at 5^h 03^m A. M., April 18, 1906, ship's time. James Denny, the chief engineer, supplies the following comment: "The ship seemed to jump out of the water; the engines raced fearfully, as though the shaft or wheel had gone; then came a violent trembling fore and aft and sideways, like running at full speed against a wall of ice. The expression 'a wall of ice' is derived from my experiences in the Arctic." In this vicinity the chart has several soundings, as follows: 911 fathoms over clay and mud at 11.5 miles on the line to Gualala Point; 1,586 fathoms over clay and ooze 8 miles north by compass; 1,821 fathoms over clay and ooze 14 miles N. 54° W. by compass.

The wharfinger at Santa Cruz reports that he heard a rumble before the shock, coming from the southeast, and saw the seismic wave traveling shoreward, causing a great rattling and crashing when it struck the town. Two distinct sets of vibration were felt, the latter being the harder. There was very little surf, the water looking like that in a tub when jarred. The wharf, extending southeast, seemed to pitch lengthwise. A steamer between Santa Cruz and Monterey, also one at Monterey wharf, felt the shock; it jarred them as if they had struck bottom.

Shocks felt at sea subsequent to April 18, 1906. — The ship *Alex Gibson*, at 7^h 05^m P. M. August 3, 1906, when in lat. 25° 35′ N., long. 110° 06′ W., experienced a tremendously heavy seaquake, lasting about 40 seconds and shaking the ship from stem to stern as if she were bumping over a ledge of rocks. It shook tools out of the racks in the carpenter shop; threw pots and pans down in the galley, cups and pitchers from hooks in the pantry, and all lamp glasses off the lamps. The crew came running aft not knowing what was the matter, and the captain thought the yards were coming down. The sea at the time was perfectly smooth, the wind light from the southwest, no land in sight, and all sail set in fine, clear weather. At 7^h 10^m P. M., ship's time, another light shock was felt, of about 15 seconds duration; and from 8 to 12 midnight two more very light shocks were felt, but the time was not noted. The captain states that he had experienced an earthquake at sea on a former occasion, but the one felt before was nothing compared to this one, either in force or duration. (Hydrographic Bureau.)

The bark *St. James*, Capt. F. O. Parker, while in lat. 26° 19′ N., long. 110° 25′ W., in the Gulf of California, on August 26, 1906, was shaken by a seaquake at 12^h 15^m P. M. The shock lasted a minute, and the sensation was as if the vessel were striking upon sunken rocks. Upon arrival at Guaymas, the captain learned that no shock had been experienced at or about the time noted. (*San Francisco Chronicle*, Sept. 16, 1906.)

The bark *Agate*, Capt. C. H. McLeod, while off the northwest coast in lat. 43° 10′ N., long. 128° 50′ W., 100 miles west of Coos Bay, experienced a heavy shock on September 2, 1906, at 3^h 45^m A. M. The shock lasted nearly 1 minute. The sensation was as if the vessel had struck a coral reef or rock. The wind was light, the weather clear, and the sea smooth. At 3^h 55^m A. M., another shock was felt, not so severe nor so prolonged as the first. (*San Francisco Chronicle*, Oct. 2 and 9, 1906. Hydrographic Bureau.)

The ship *Robert Searles*, Capt. J. H. Piltz, while in lat. 41° 78′ N., long. 125° 52′ W., 85 miles northwest of Cape Mendocino, experienced a severe shock on September 14, 1906, which occasioned a panic among the crew. The cargo (lumber) and upper works of the vessel were shaken. The shock lasted 25 seconds. (*San Francisco Chronicle*, Sept. 17, 1906. Hydrographic Bureau.)

The American schooner *Stanley*, Capt. K. Petersen, while in the calm center of a cyclone, in lat. 46° 09′ N., long. 125° 22′ W., 55 miles west of Cape Disappointment, on November 6, 1906, felt a sharp shock that lasted 2 or 3 seconds. Immediately afterwards, when looking toward the southwest, the captain saw 3 mountainous waves coming; when they struck, the ship began to pitch and roll violently, and he thought every minute she would be swamped. (Hydrographic Bureau.)

The schooner *Melrose*, Capt. M. McCarron, while in lat. 37° 35′ N., long. 123° 35′ W., felt a seaquake on February 3, 1907. The first shock was at 10^h 30^m A.M., lasting about 8 seconds; and the second at 10^h 50^m A.M., lasting about 5 seconds. Neither shock was violent, but each caused a decided trembling of the vessel. The motion was from east to west. The sky was overcast and the sea was smooth, with light westerly winds. The position of the vessel was 28 geographical miles S. 73° W. from the Southeast Farallon. The nearest sounding on the chart is 5 miles north of this position, where there is shown 1,726 fathoms of water.

NUMBER OF MAXIMA IN THE MAIN SHOCK.

In response to various circulars sent out by the Commission, and to direct inquiries by the members of the Commission or their aides in the field, 154 replies have been received, which constitute testimony as to whether the main shock comprized one or more maxima. Many of these replies are rather questionable scientific evidence, inasmuch as many of them were in response to a leading and suggestive question, and very few of them have been subjected to the clarifying process of cross-examination. So few people were awake at the time the shock began that but a small proportion of the replies come from people who were in full possession of their observational faculties at the beginning of the disturbance; and of those who were suddenly and rudely awakened, few were sufficiently alert for deliberate perception at the time and had to rely upon a somewhat confused memory for the character of the shock. Yet the testimony is of value, and indicates a very general consensus of the impression that there were 2 principal maxima in the shock; and the failure of many to recognize or remember 2 parts to the shock does not seriously invalidate the testimony of those who received that impression.

Of the 154 replies received, 98 testify to 2 maxima; 46 to but one maximum; 9 to 3 or more maxima; and 1 to more than one. Of the 98 who reported 2 maxima, 67 discriminated between the 2 parts of the shock, as to their relative intensity; and of these 67, there were 48 who had the impression that the second maximum was the more severe, and 19 who thought it the less severe. Of the 46 who recognized only one maximum, 32 were beyond the zone of destructive effects, where the intensity was VI or less (in a few cases VII); and of the remaining 14 cases within the zone of destructive effects, 11 were offset or contradicted by other reporters in the same general district as themselves, who record two maxima. It would thus appear that within the zone of destructive effects, say out to isoseismal VII, the evidence, such as it is, points unmistakably to the occurrence of 2 maxima; and the prevailing opinion is that the second was the stronger. The failure on the part of many reporters to discriminate 2 parts of the shock beyond the isoseismal VII is not surprising, and is offset by the considerable number of reports in which 2 maxima were noticed.

List of observations as to the number of maxima in the earthquake shock.

Locality.	Reporter.	No. of Maxima.	Remarks.
Nolton	Clara Ward	2	Second stronger.
Crescent City	G. Sartwell	2	Interval about 2 seconds.
Montague	C. H. Chambers	1	Duration 30 seconds.
Upton	G. R. Dixon	1	
Big Bar	W. A. Pattison	2	A tremor which eased up, then another stronger.
Papoose	C. B. Lakemore	1	
Eureka	A. H. Bell	1	Maximum intensity toward end; duration 47 s.
Fortuna	D. L. Thornberry	2	One greater than the other.
Pepperwood	J. F. Helms	2	Second stronger.
Briceland	J. W. Bowden	2	Second stronger.
Fort Bragg	E. Huggins	2	Continuous shock, 40s., ending withh eavy one.
Glen Blair	A. P. Scott	1	
Albion	J. Coyle	1	
Philo	J. L. Prather	2	About the same intensity.
Fish Rock	J. F. Mell	2	Second stronger.
Annapolis	G. W. Fiscus	2	First in wave motion; second rotatory.
Fort Ross	G. W. Call	Several	Increased in force up to third or fourth.
Cazadero	E. H. L. Cowley	2	Second stronger.
Hemlock	C. D. L. Bowen	2	Second stronger.
Cloverdale	M. C. Bale	Several	Oscillatory, ending with series of shocks.
Lakeport	J. Overholser	1	
Sanhedrin	V. L. Frasier	1	
Oathill	J. J. Hulter	2	Second stronger.
St. Helena	F. Blachowski	2	Second stronger.
Veteran's Home	A. Brown	1	
Wooden Valley	H. W. Chapman	2	First stronger.
Cotati	C. L. Jeffrey	1	

List of observations as to the number of maxima in the earthquake shock — Continued.

Locality.	Reporter.	No. of Maxima.	Remarks.
Vallejo	J. J. Lindunger	2	Increase in severity in latter half.
Tamalpais	W. W. Thomas	2	If any difference, first stronger.
San Rafael	L. Reubold	2	First light and long, second hard and short.
do	E. Landon	1	
do	A. Scott	2	First light, second heavier.
do	G. L. Richardson	2	First heavier.
do	F. M. Watson	2	First lighter and longer than second.
do	J. D. Bennett	2	First heavier.
San Mateo	B. A. Peckham	3	First and second were heavy wavy motions; third was short rapid trembling.
do	R. Anderson	2	Two main thrusts or sets of movements.
Mountain View	A. M. Free	2	Second stronger.
Woodside	H. O. Beaty	2	Personally observed but 1; others observed 2 or 3 and there is a general agreement that second was stronger.
San Jose	J. C. Hartzell	2	Second more intense.
do	M. Connell	1	Came suddenly, explosion-like, then a violent swaying.
Santa Clara	J. S. Ricard	2	Two shocks, then finally a twist and an uplift.
Campbell	F. M. Righter	2	Second stronger.
Los Gatos	F. H. McCullogh	1	Wife noticed a preliminary shaking.
do	I. H. Snyder	2	Partial intermission of 1 or 2 s. Second much stronger.
do	W. S. T. Smith	2	Interval was not sufficient to allow moving objects to come to rest.
Skyland	T. Wightman	1	
New Almaden	J. F. Tathan	2	Second stronger.
Wright	Mrs. A. L. Sears	1	Followed by tremors.
do	Flora E. Beecher	2	About equal.
Gilroy	W. J. Lawler	2	Second stronger.
Sargent	W. B. Stuart	2	First stronger.
Hollister	J. N. Thompson	2	Almost continuous; second did most damage.
Tres Pinos	G. A. Waring	2	
Paicenes (4 miles SW.)	do	1	
Bear Valley	do	3	Noted by several people.
Bitterwater	C. Z. Smith	2	Second stronger.
Hernandez	E. M. Tucker	2	First part gentle, second more severe.
Mt. Hamilton	H. K. Palmer	2	First harder; memory uncertain.
do	A. M. Hobe	2	Jar, then pause, then tremble.
do	W. W. Campbell	2	First harder.
Calaveras Valley	R. Ingleson	2	2 separate shocks.
Livermore	E. G. Still	2	
Danville	A. E. Clark	2	Second stronger.
Mt. Eden	W. Gally	2	First sideways, second upward.
Mills College	J. Keep	1	
Berkeley	A. C. Lawson	2	First prolonged, with secondary maxima; second brought down chimneys and ended rather abruptly.
Bolinas	J. G. Peter	2	Second stronger.
Farallones	J. A Boyle	2	First stronger.
Santa Cruz Range	M. Doyle	2	Tremor, then distinct shock; then violent shock, then tremor.
Bellvale	Lilla E. Bell	2	Continuous shake with 2 heavy parts.
Santa Cruz	G. A. Waring	2	Second stronger.
do	D. J. Lincoln	2	
Delmas Seabright Twin Lakes	G. A. Waring	2	Shock came suddenly, diminished, then at a second jolt the chimneys fell.
Bonnie Doon	T. R. Thayer	2	Second stronger.
Soquel	Matilda Baker	2	First stronger.
Ben Lomond	D. R. Guichard	2	Second stronger.
Watsonville	E. McCabe	1	
Castroville	G. A. Waring	1	Felt as 1 continuous vibration.
Prunedale	H. H. McIntyre	2	Second stronger.
Salinas	Bertha M. Abbott	2	Second stronger.
Monterey	N. W. James	2	First stronger.
Chualar	G. P. Anderson	2	
Lonoak	J. Rist	1	Continuous shock, light at first; finishing with a hard stroke and twist.
Shandon	C. J. Shaw	2	

List of observations as to the number of maxima in the earthquake shock — Continued.

Locality.	Reporter.	No. of Maxima	Remarks.
San Luis Obispo	S. D. Ballou	1	
do	J. R. Williams	1	50 seconds long.
do	M. R. Venable	2	Slight tremor; then a second more severe; then a distinct oscillation, quite hard; then a tremor.
Santa Maria	F. R. Schanck	3	First and second, 1 or 2 s.; third, 12 to 15 s.
Pismo	Emma M. Patchett	2	Second stronger.
Lompoc	A. McLean	1	One long shock.
do	C. K. Studley	2	First gradually increased to maximum and gradually decreased. Second died suddenly.
Santa Barbara	J. A. Dodge	1	About a minute long.
do	S. F. Hunt	3	Second strongest.
Los Angeles	W. D. Fuller	1	
Compton	L. A. Rockwell	2	First stronger.
Azusa	A. P. Griffith	1	As if house had been struck by heavy blow.
Toluca	W. C. Meddington	2	
Redding	L. F. Bassett	1	
Colusa	F. Roche	More than 1	Shock would die out, only to return again.
Meridian	T. J. Taylor	2	Second stronger.
Marysville	R. F. Watson	2	First lasted about 45 s.; the second about 90.
Rumsey	J. M. Morrin	2	Second stronger.
Guinda	J. Jacobsen	1	Continuous shake.
Capay	S. Schwale	1	Continuous shake.
Woodland	I. A. Morris	2	First stronger.
Plainfield	H. O. Purington	2	First stronger.
Black's Station	S. P. Cutler	2	First stronger.
Knight's Landing	L. T. Shamp	2	First stronger.
Sacramento	J. A. Marshal	2	Oscillation ended in 2 jars, with appreciable time between.
Fairoaks	L. M. Shelton	1	One straight shake, very light.
Main Prairie	Mrs. A. Rattike	1	
Binghamton	W. H. Smith	2	Second stronger.
Collinsville	J. Antonini	4	Second stronger.
Ione	J. F. Scott	2	Second stronger.
Stockton	E. P. Higby	2	Of equal strength; interval of a few seconds.
Oakdale	E. C. Crawford	3	Second stronger.
Turlock	J. L. Brown	1	
Westley	W. G. Carey	2	Second stronger.
Merced	F. J. Reidy	2	Second stronger.
Madera	F. E. Smith	2	30 s. and 60 s.; second stronger.
Fresno	J. P. Bolton	2	First stronger.
Jameson	W. J. Williams	2	
Kingsbury	A. B. Loomis	1	
Riverdale	W. Lenson	2	Second stronger.
Visalia	A. M. Doty	4	Last most pronounced.
Exter	H. R. Stephens	2	Nearly equal in intensity.
Bakersfield	A. G. Grant	1	10 seconds.
McArthur	J. McArthur	2	First stronger.
Susanville	J. Branham	1	Probably 2 s.
Quincy	L. A. Barrett	1	
Kittle	F. Campbell	1	
Beckwith	J. W. Middleton	2	Not sure; there was a wavelike motion, with a sudden jar at the end.
Boca	A. E. Duswell	1	60 s.
Stirling City	H. B. Weaver	1	
Paradise	F. W. Day	2	Second stronger.
Allegheny	W. A. Clayton	2	
Pino Grande	W. E. Basham	1	
Nashville	J. C. Heald	1	
West Point	J. A. Wilson	1	
Railroad Flat	E. Taylor	1	
Milton	J. H. Southwick	2	Second stronger.
Tuolumne	J. T. Thompson	2	
do	J. E. Coover	1	
LaGrange	J. A. Hammond	2	Second stronger.
Sequoia	M. Crocker	2	2 prolonged light shocks.
Darrah	R. Darrah	2	Second stronger.
Fresno Flats	Postmaster	1	
Gold	T. J. Rhodes	2	Both about the same; quite heavy.
Magnet	?	1	
Mono Lake	E. A. Benedict	2	First stronger.
Laws	G. D. Louderback	2	First gentle rocking; second small jerks.
Lone Pine	do	2	A few seconds apart.
do	G. F. Marsh	2	First stronger.

SOUNDS CONNECTED WITH THE EARTHQUAKE.

An interesting manifestation of the earthquake was the sound which was heard by many people in connection with the shock. Appended is a tabulated statement of the testimony bearing upon this phenomenon, if it may be so called. In this tabulation there are recorded 81 observations of people who heard sounds, without segregating those which are reported in a summary way as the common experience of "some," "several," or "many" persons. Of these, 40 report having heard sounds before having felt the shock; 14 report the sound as accompanying the shock or coincident with it; 3 heard a sound after the shock; and 19 report having heard unusual sounds at the time of the earthquake, without further specification. Besides this, there are 3 reports of sounds having preceded after-shocks, one case where the sound was observed to precede the second phase of the shock but not the first, and one case where sound was heard but no shock was felt. The observations are fairly well distributed over the region affected by the shock. Besides these observations of a positive kind, there were many cases reported where no sound was heard, altho the people were awake.

In view of the 40 positive and independent observations of sounds having preceded the shock, with, in some instances, specific evidence of actions induced by the sound having been engaged in during the interval between first hearing the sound and feeling the shock, there can be little question that sound vibrations of the air actually preceded the sensible shock. The testimony of the 14 persons who heard the sound during the shock does not contravene that of the 40 who heard it before, nor does that of the 19 persons who do not particularly specify the time relation of the sound to the shock. Sounds heard before the shock may well have continued thru the shock and come to the attention of less alert people only when the shock was felt. The three observations of sounds preceding the after-shocks are corroborative of the 40 referring to the main shock. The one case near Alturas, where men in camp heard a sound but felt no shock, is an interesting and exceptional, but credible, one.

The evidence as to the character of the sounds is consistent and uniform. They were vibrations low in the scale. This fact suggests an explanation of the failure of certain people to hear the sounds when others in the same vicinity observed them. It may be that the vibrations in question are below the range of audibility of some people and within that of others. With this question in mind, an inquiry was addrest to Prof. G. M. Stratton of Johns Hopkins University, in regard to the limit of sound. His reply was as follows:

> The lowest limit of sound is so differently given by different investigators that it seems clear that individual differences play an important part. The limit is placed all the way from 8 to 30 double vibrations a second, and that may represent the range of personal variation; but more probably it varies between 16 and 30; and those who think they hear as low as 8 are in reality hearing the second partial of that tone, viz., 16 d.v. This, of course, applies only to the perception of tone; for of repeated shocks at a very low rate we can still hear the separate shocks, *e.g.*, puffs or blows, but they do not as yet fuse into a continuous tone.[1]

Now if it should be a fact that the rumbling sounds which preceded the shock fall within the range of from 16 to 30 double vibrations per second, then from the probability set forth by Professor Stratton, the auditory organs of some people would be sensitive to such vibrations, while those of others would not.

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[1] Professor Stratton refers to a chapter on "Tiefe und Tiefste Töne," in Helmholtz's Lehre von der Tonempfindungen, where the difficulties of accurate determination and the different things that appear in such tones are well set forth.

Another interesting question to which the testimony gives rise is: How do such vibrations reach any locality in advance of the shock? The seismic waves traverse the earth's crust very much more swiftly than sound-waves do the air, so that it is a physical impossibility for sound-waves generated in the air above the seat of disturbance to outreach them. The vibrations observed as sounds must, therefore, be transmitted to the atmosphere by tremors of the ground which precede the larger waves, and which are not otherwise perceptible to the senses ordinarily. These doubtless correspond to those phases of seismic movements which are recorded by delicate instruments and are known as "preliminary tremors."

Noises heard at the time of the shock.

Locality.	Reporter.	Observer.	Kind, direction, time of noise, etc.
Ferndale	A. W. Blackburn	Same	Accompanying the quake was a rumbling, roaring sound.
Covelo	E. S. Larsen	Large proportion of residents	Roar just preceding earthquake shock.
Fort Bragg	O. F. Barth	A man	The wave traveled SW. and a roar accompanied it.
Mendocino	Wm. Mullen	Same	Unusual rumbling sound like distant thunder, preceding shake, being loudest at commencement of disturbance.
Albion	J. Coyle	Same	Roaring noise like heavy fall of hail coming from ocean to the west.
Point Arena	W. W. Fairbanks	Not named	Heavy roaring sound preceded the shock.
Point Arena Lighthouse	do	Keeper	Blow came quick and heavy, accompanied by heavy report.
Upper Lake	C. M. Hammond		A roaring noise past off to SW.
do	do	Workmen	A noise in the trees as tho heavy wind were blowing thru them; then the rumbling past off to SW.
Cloverdale	M. C. Bale	Many persons	Rumblings before the shock.
Healdsburg	H. R. Ball	Same	Attended by great rumbling noise, as thunder.
Santa Rosa	Miss F. Locke	R. Worthington	Heard roaring.
do	do	Mr. Campbell	Heard a great roaring 2 s. or 3 s. before the shock.
do	do	Watchman	Heard noise in SW.; then felt breeze; then felt shock.
do	do	Mrs. Lloyd	Heard noise; ran to window and opened it; then shock came.
do	do	A man	Heard roaring and saw wave of earth 2 feet high.
Cotati	C. L. Jeffrey	Same	Sound as of a strong wind before shock.
Tomales	do	A boy	Heard roaring and said, "Oh, there's thunder," before the shock.
do	do	A farmer	Heard roar from SW.
do	do	Mr. Goudy	Heard a great roaring sound from SE.
Point Reyes Station	do	A farmer	Heard roar, then felt wind on my face.
Olema	do	A dairyman	Heard noise in the ground, got up, then felt shock.
Bolinas	K. Easton	Same	Rumbling noise preceded one after-shock on April 18.
Calistoga	Dan Patten	Same	A rushing noise before shock came.
Napa	T. Hull	Not named	A rumbling, then came shock.
Alturas	C. B. Towle	Some men in camp	Heard low sound of earthquake, but did not feel shock.
Redding	L. F. Basset	Same	Noise resembled a passing train; it preceded and outlasted the shock.
Chico	E. Mayhew	Same	Rumbling sound thruout the disturbance like heavy-laden wagon passing house.
Willows	A. W. Schorn	Same	Unusual rumbling sound preceded shock, gradually grew louder, and died away with the shaking.
Colusa	Fred Roche	Same	Sound like an approaching train coincided with shock.
Berkeley	Miss F. Locke	Capt. Fire Dept.	Was awakened by roar 5 s. before shock.
San Francisco	M. C. Erskine	Same	Awake at $5^h 10^m$ A.M. Heard a great roaring from NE.; soon the shock came from same direction.

Noises heard at the time of the shock.—Continued.

Locality.	Reporter.	Observer.	Kind, direction, time of noise, etc.
San Francisco	T. J. J. See	Lieut. Bertholf and other officers	A low rumbling preceded earthquake.
Peninsula of San Francisco	R. Anderson	Many persons	Noise accompanying the shock; indescribable noise associated with main shock; immediately after the shock.
San Mateo	B. A. Peckham	Mr. Maxwell	Heavy rumbling which he took for thunder, from NW., before shock.
San Jose	Mr. Connell	Same	An undertone, rumbling sound coincided with beginning of shock.
do.	W. S. Prosser	Several good observers outdoors	The noise of the quake came from SE. and died away toward San Francisco.
Santa Clara (3 mi. west)	I. H. Snyder	D. Pickering	Sound compared to stampede of cattle.
Congress Springs	J. C. Branner	Residents	Shock accompanied by rumbling; aftershocks preceded by sound like a blast.
Los Gatos	I. H. Snyder	Mr. Land	Premonitory roar came from south.
do.	W. S. T. Smith	Same	No sound heard for main shock, but muffled sound heard just before each minor shock.
do.	F. H. McCullogh	Same	Sound as of bad storm coincident with first and worst of shock. Later in the day there was a rumbling sound to me (deaf) not unlike a distant detonation.
Wright, 4 miles south of	L. E. Davidson	Same	Attention first drawn to a slight rumbling noise.
Glenwood	Miss F. Locke	Different persons	After every shock on April 18 was a rumble like that of artillery.
Scott Valley (Santa Cruz County)	do.	Mrs. Field	Tremendous roaring in NE.
Santa Cruz	G. A. Waring	Wharfinger	Rumble before shock.
Santa Cruz Lighthouse	do.	Keeper	Noise as of a wagon crossing a bridge preceded every quake.
Wilder's Dairy N. W. of Santa Cruz	do.	Not named	Shock preceded by rumbling from south.
Swanton	do.	do.	Distinct noise as of team crossing a bridge to NW. preceded every shock.
Ano Nuevo Lighthouse	do.	Keeper	Distinct rumbling preceded shock.
Pescadero	do.	Some people	Noise as of wind preceded the shock.
Castroville	do.	Not named	Shock described as beginning like a subterranean blast.
Salinas	Bertha M. Abbott	Same	Rumbling noise coincided with shock.
San Lucas	G. A. Waring	Not named	Sound reported to have been heard.
Fort Romie	do.	Not named	Noise heard after shock.
San Luis Obispo, 1 mile east of	do.	do.	Great roar heard.
New Almaden (Hacienda)	do.	Not named	Loud noise like thunder traveled northward, distinctly preceding shock.
Coyote	do.	A man	Noise from SE. seemed to pass over him.
San Martin	do.	A man	Heard roar, horse became frightened before shock came.
Gilroy to Hollister	do.	Various persons	Rumble heard all thru region from Old Gilroy and San Filipe to Hollister. One said from SE., another from SW.
Tres Pinos	do.	Not named	Distinct rumble preceded shock at Palmtag's winery.
Bell's Station	G. F. Zoffman	do.	Rumble distinctly heard before the shock.
Paicenes	G. A. Waring	do.	Distinct noise preceded shock at Cienega Lime Kilns.
Hernandez	do.	do.	No noise before quake, but report as of blast immediately preceded second (hardest) period of vibration.
Mt. Hamilton	K. Burns	Same	Sound as of flight of birds simultaneous with shock.
Calaveras Valley	G. F. Zoffman	R. Ingleson	The two separate shocks accompanied by roaring sound from north.
Modesto	E. Hughes	Several persons	Roaring or rumbling sound beginning a few seconds before and continuing until end of disturbance.
do.	do.	Green Bros.	Roaring sound just before shock.
do.	do.	Mr. Elsey	Rumbling sound.

Noises heard at the time of the shock — Continued.

Locality.	Reporter.	Observer.	Kind, direction, time of noise, etc.
Modesto	E. Hughes	A. H. Holtman	Shock preceded by roaring sound.
do	do.	H. Hintze	Rumbling sound.
Stockton	do.	Some persons out of doors	Dull rumbling sound just preceding shock; some think it emanated from buildings.
Westley	W. G. Carey	Men sleeping on scow on river	Heard terrible rumbling 30 s. before shock; came out of scow to see what it was, then shock came.
Conejo	E. Picket	Same	Awakened by noise like locomotive coming at full speed.
Santa Barbara	J. A. Dodge	Neighbors	Rumbling just before shock.
Lone Pine, Nevada	G. F. Marsh	Same	Slight rumbling sound like wind blowing.
Ballarat, Inyo County	D. C. Pickett	Same	Awake and up. First indication of earthquake was low, distant, and increasing roar.

VISIBLE UNDULATIONS OF THE GROUND.

The earth-waves generated at the fault past thru the earth's crust with a velocity of probably from 2 to 3 kilometers per second. The undulations of the surface due to the passage of such waves would be so swift that they would scarcely be observed visually. Yet there is considerable testimony, of a consistent and independent character, that much slower undulations were observed. This testimony comes from various parts of the region disturbed, and a great deal of it is positive and unequivocal as to what seemed to be the fact. The evidence indicates that there is a type of wave in the ground, in the region of high intensity, which has not yet been sufficiently recognized, and the origin of which is obscure. Some 20 or more observations bearing upon this class of phenomena are here summarily recorded:

Judging from the descriptions given, these waves behaved like undulations in water, with an oscillation approximately normal to the surface. They were for the most part observed on alluvial tracts, but some of the reports come from districts where there is but a thin veneer of alluvium or soil upon the rocks. If it should prove, on the basis of more abundant evidence, that these waves are peculiar to alluviated basins, they may be explained as reflections from the rocky slopes of such basins. If a bowl of liquid be tapt smartly, vibrations are inaugurated in the rigid bowl which have a speed so great that the secondary waves generated in the liquid pass out from all parts of the walls of the vessel sensibly at the same instant. But the secondary waves thus generated in the liquid have so slow a rate of propagation that they are quite apparent to the eye, and in the central part of the surface of the liquid, when the waves meet, there is a violent commotion. If, instead of a bowl of liquid, we have a rock basin filled with water-saturated alluvium, it seems probable that a similar effect would be produced in a modified degree; and the visible waves at the surface may have had such an origin. But whatever be their origin, it is apparent that they must be a large factor in damaging structures situated upon the ground in which they occur, and so raising the apparent intensity on any scale based on destructive effects.

Freshwater, Humboldt County (S. E. Shinn). — My orchard raised up between 2 and 3 feet like a big breaker coming in.

Ferndale, Humboldt County (A. W. Blackburn). — Those who claim to have been out of doors when the shock came, state that the earth rose and fell like the waves of the sea.

Fort Bragg, Mendocino County (O. F. Barth). — A man walking along the street was thrown down. He is positive the wave traveled southwest. The ground undulations were 2 and 3 feet high.

Point Arena, Mendocino County (W. W. Fairbanks). — The ground moved in undulating swells or waves, rising and falling.

Santa Rosa, Sonoma County (Miss Locke). — A man saw an earth-wave 2 feet high.

Cotati, Sonoma County (C. L. Jeffrey). — The surface of the earth waved like water.

Napa, Napa County (T. Hull). — Those who were out of doors say the trees bent as the shock came like a wave of the ocean.

Pleasanton, Alameda County (Miss F. Locke). — A lady near Pleasanton saw the earth go in waves like the ocean.

San Francisco (Miss F. Locke). — A fireman at the engine house 1757 Waller Street said the ground went in waves.

San Mateo, San Mateo County (Mr. Maxwell). — The earth rose and fell like the swell of the sea, the swells being about 3 feet high.

Saratoga, Santa Clara County (Louise M. Atkinson). — Distinct waves past over the ground from northwest to southeast, the orchard trees rising and falling on each wave, like ships at sea, while the electric poles along the road leaned this way and that, some seeming almost to touch the ground.

Santa Clara, Santa Clara County (I. H. Snyder). — Mr. Dan Pickering, living a mile south of Santa Clara, says that the ground rose and fell in waves about a foot high. Others say that the orchards seemed to be agitated by a wave-like motion.

San Jose, Santa Clara County (W. S. Prosser). — Many persons saw waves in the ground. Sifting out exaggerations, these appeared to be rather more than a foot in height. The best observer estimated the distance from crest to crest at 60 feet; others much less, but they must have been greater, for there is no evidence which shows any such vertical cracks as would have been produced by short waves. A good observer 6 miles southwest of San Jose described the waves as parallel with certain tree rows which are northeast and southwest; and the waves moved from him at right angles to the line toward San Francisco. Another person, 6 miles northwest from San Jose and looking south, saw the waves (which he thinks were east and west) coming toward him, and hence toward San Francisco; but about the middle of the quake these were met by other waves and the whole surface resembled hillocks or cross seas, and the tree-tops waved wildly. To the man to the southwest of San Jose, however, the tops of the trees were almost still, while the trunks waved sinuously.

Meridian, Santa Clara County (G. A. Waring). — A lady reports seeing waves traveling southward along the driveway, and a man reports seeing a heavy wagon move back and forth several times, 4 or 5 feet along the driveway.

Campbell, Santa Clara County (F. M. Righter). — People out of doors at the time state that there was a very rapid wave-like motion of the surface of the earth.

Wright, Santa Clara County (Flora E. Beecher). — Mr. Deacon, our neighbor, rose and stood by the window, and he declares that the ground rose in waves.

Coyote, Santa Clara County (G. A. Waring). — Near Coyote a man reports having seen a northwest-southeast fence move in a wave-like motion, beginning at southern end.

Paicenes, San Benito County (G. A. Waring). — Toward the Cienega Lime Kilns, 4 miles south of Paicenes, a man reports seeing a wave coming westward thru a grain field.

San Lucas, Monterey County (G. A. Waring). — West of San Lucas the waves were reported to have been seen moving southward over the hills.

San Luis Ranch, near Pacheco Pass (G. F. Zoffman). — Mr. Mills stated that the surface of the ground moved up and down like the waves of the ocean.

Mendota, Fresno County (G. F. Zoffman). — The people who observed the plains at Mendota said that they assumed a wave-like appearance, and that the trains rose and fell as the undulations past beneath the tracks. They also stated that this wave-like appearance was confined to the north and south movement, the east and west motion being more in the nature of a tremor.

Visalia, Tulane County (F. A. Swanger). — The movement of swell and fall of wave seemed strong.

PATHOGENIC EFFECTS OF THE EARTHQUAKE.

A curious and fortunately trivial effect of the earthquake was the production of nausea. This was observed especially in the region of slower motion of the earth, beyond the zone of destructive effects, but one or two cases being reported from the region of high intensity. The sickness produced was in most cases apparently similar to seasickness, and ascribable to the swaying of the ground. In the few cases which occurred in the region of quick motion, the nausea was more probably due to nervous shock. Brief mention is here made of the cases reported, tho there were probably many others.

At Ruby, in Siskiyou County (R. E. Madden), intensity III–II, persons were slightly nauseated or rendered dizzy, but the feeling past instantly. At Upton, Siskiyou County (E. R. Dixon), intensity IV–III, people felt seasick. Mr. J. H. Roberts, of Yuba City, intensity VI–V, reports that 5 persons on his place were made quite sick. In Marysville (R. F. Watson) the shock caused a dizzy feeling. At Stockton (E. Hughes), intensity VI, a considerable number of people suffered from nausea and dizziness, with headache, for a time after the shock. With some these disagreeable symptoms persisted all the following day. At Modesto (E. Hughes), intensity VI, a number of people were affected by symptoms somewhat like those of seasickness for several hours after the shock. San Francisco (Miss F. Locke). Mrs. E. was nauseated by the earthquake and felt pains in her heart. Several people were nauseated by the motion of the ground at Pescadero, San Mateo County, intensity VIII–VII. (G. A. Waring.)

In Bear Valley, San Benito County (G. A. Waring), intensity VI–V, a man out-of-doors became dizzy and nauseated, but did not at the time realize the cause. Thru the south end of the valley several people became dizzy. Between Mendota and Coalinga (G. F. Zoffman), intensity VII–VI, many persons suffered from a nauseating sensation. At Conejo, Fresno County (E. Pickett), intensity VI, the earthquake made some people sick at the stomach. At Santa Barbara (J. A. Dodge), intensity III, a woman who was out-of-doors at the time of the shock was made slightly dizzy. In Gardnerville, Nevada (J. A. Reid), intensity IV, a number of people complained of a feeling of nausea while eating breakfast at the time of the earthquake, but they felt no motion. At Yerington, Nevada (G. D. Louderback); intensity IV–III, one person experienced a dizzy sensation. At Lone Pine, Nevada (M. S. Dearborn), intensity IV, a good many people when they first felt the shock thought that they were simply dizzy.

EFFECT OF THE EARTHQUAKE ON ANIMALS.

Miss Finette Locke, of Santa Cruz, has interested herself in an inquiry into the behavior of animals at the time of the earthquake, and has prepared lengthy notes reciting incidents which were reported to her as the effect of the main shock and the aftershocks upon animals in various parts of the Coast Ranges extending from Santa Rosa to Santa Cruz. Her notes, which refer chiefly to domesticated animals, form the basis for the following summary statement:

Horses. — Horses whinnied or snorted before the shock and stampeded when the latter was felt, some falling owing to the commotion of the ground. Horses in harness became frightened and ran away, while others stopt and screamed. Some horses with riders in the saddle stumbled and fell; others stood and shivered. A mule near Santa Rosa refused to eat all day. A farmer in the same neighborhood observed his horses moving about, whinnying and snorting, and called to his boy, who was with them, inquiring what was the matter, but before the boy could answer he felt the shock. In a stable of 30 horses on Alabama Street, San Francisco, all reared, snorted and jumped before the stable-man, who had just fed them, knew the cause of the trouble. Of the 30, all but 5 broke their halters and came toward the stable-man, who had to keep them off with a pitchfork. Several horses at the various engine houses of the San Francisco Fire Department became frightened and broke away from their stalls. In stables generally horses broke away from their stalls, and some failing to break loose lay down.

Cattle. — Cattle on the hills came down to lower levels, and in some localities did not return to the hills for some days after the shock. Cows in corrals near the fault-line were in many localities thrown to the ground; others stampeded and ran about wildly. At Olema cows in the milking corral were thrown to the ground and rolled over, and as soon as they could stand they stampeded. The stampeding of cows from the milking corral was reported at many ranches. Several instances were reported where cows stampeded before the shock was felt by the observer. In other cases cows about to be milked are said to have been restless before the shock and to have lain down as soon as the shock was felt, some giving less milk than usual. Two cows near Duncan's Mills are said to have died as a result of the shock. Several cows dropt calves prematurely. Lowing and bellowing of the cattle at the time of the shock was very commonly reported, and in some cases this is said to have occurred a little before the shock.

Cats. — Various reports regarding the behavior of cats at the time of the earthquake and the after-shocks indicate that they became alarmed. Some rushed about wildly, with big tails and bristling backs; some hid in dark corners and otherwise behaved abnormally; some disappeared for several days after the shock. In the after-shocks, cats seemed to perceive the tremor before people did, and crouched in fright or ran. At Olema 7 cats were not seen for 2 days after the shock, and in Alameda some cats disappeared for 3 days. Some carried off their kittens.

Dogs. — Dogs generally became alert before the after-shocks, and barked, whined, or ran to cover. After the shock some ran away and did not return for a day or several days. Some barked at the time of the shock and ran about with their tails between their legs. Many sought the protection of houses and stayed close to people after the shock. One dog near Santa Rosa ran about the house for 10 seconds before the shock was felt, and then jumped out of an open window down one story to the ground. Some dogs were in an excited condition, running about vaguely for some time after the shock; and this was repeated at the after-shocks. Others ran straight away at full speed. Some bitches brought their puppies to what apparently seemed to them safer quarters. Some took to their beds for several days after the shock and others refused to eat. The most common report regarding the behavior of dogs was their howling during the night preceding the earthquake.

Chickens.—Chickens generally ran for shelter to their houses, with their wings outstretched, squawking.

Wild animals in confinement. — The wild animals in confinement at the Chutes, San Francisco, crouched and remained quiet during the shock, but roared after it was over, led by the elephant. The elephant also roared at the times of the after-shocks.

MINOR GEOLOGICAL EFFECTS OF THE EARTHQUAKE.

LANDSLIDES.

There are three types of landslides known in the Coast Ranges. For convenience in reference they may be designated as earth-avalanches, earth-slumps, and earth-flows. The first and last of these are of somewhat exceptional occurrence, but the second is exceedingly common. These landslides are of geological importance as an agency concerned in the evolution of the geomorphy of the Coast Ranges of California to an extent equaled in few other regions; and it becomes a matter of interest to appreciate the rôle played by earthquakes in promoting the efficiency of this agency. The activity of all three kinds of landslides is related directly or indirectly to the earthquake of April 18, 1906. In order to appreciate certain phases of the relationship, it will be of advantage to state briefly, in a general way, some of the characteristics of these different types of landslides. In doing this, reference will first be made to the most commonly occurring type, the earth-slump. The other two may then be characterized by contrast with this type.

Under normal conditions, earth-slumps appear chiefly as features of mature slopes which are in adjustment to the ordinary processes of rain erosion. They are also found, however, as notable features of immature slopes, at the base of which horizontal corrasion is active, as on sea-cliffs and stream-cliffs, supplanting under certain conditions the earth-avalanche which is chiefly found in such situations. On the mature slopes of the Coast Ranges of California, under present climatic conditions, the regolith or mantle of decomposed rock, on the more common rocks, appears to be accumulating at a somewhat faster rate than the rain-wash can remove it. This excessive accumulation of the regolith appears to be an important factor in producing conditions conducive to earth-slumps. The climate of the region is characterized by a pronounced alternation of dry and wet seasons. In the summer the soil and regolith on the hillsides are dried out to a considerable depth, in many cases down to the underlying firm rock; and as the desiccation proceeds the soil shrinks and cracks. The cracks thus formed permit the ready access of the early winter rains to the deeper portions of the soil and regolith. The concentration of the entire rainfall in one half of the year is also more conducive to the saturation of the ground than if it were distributed thruout the year. The climate is thus a contributory factor to the prevalence of earth-slumps.

A factor of local importance is the character of the underlying geological formations. Where these consist of clays or shales, earth-slumps are much more liable to be inaugurated and to recur than where the rocks have little or no clay in them. The emergence of springs on hillsides is also a fruitful cause of earth-slumping where other conditions, particularly the last mentioned, are favorable. Another factor may be the recent subjection of the hill-slopes to grazing and tillage. In general, however, this interference with natural conditions appears to have been conducive to excessive corrasion and sapping, rather than to slumping. Grazing and tillage rob the surface of its natural protection of dead grass and other vegetation, which in the early winter season tend to restrain the rapid flow of the rain-water and its concentration in lines of corrasive activity. New lines of corrasion are thus inaugurated, and where the rocks are but slightly coherent new geomorphic forms, of the bad-land type, are evolved with startling rapidity. This corrasive process is sometimes complicated by earth-slumping.

The activity of earth-slumping as a degradational process is, in general, a function of the amount of rainfall in any given season. Thus in the winter of 1889-1890, in which the rainfall was exceptionally heavy, earth-slumps thruout the Coast Ranges were much more active than in seasons of normal rainfall, and many new ones were started. In all such earth-slumps the saturation with water of the soil and regolith, and in some cases of the underlying formations, is an essential condition. This water is the main agent in loosening or disintegrating the material preparatory to the slip. It is also a motive power on account of the large addition which it makes to the weight of the unstable mass; and it is a transporting agent owing to the fluid or plastic nature which it imparts to it.

The character of the movement in an earth-slump is noteworthy. The ground moved drops away from the slope in the form of a bite, leaving a lunate or horseshoe-shaped scarp overlooking the sunken area. As the mass moves down, it generally encounters the resistance of more stable portions of the slope below, and is thus crowded upon itself. The plastic mass is in this way deformed, and the deformation amounts in many cases to an effective rotation of the moved portion upon a horizontal axis. The lower portion is thrust over the passive ground at its lower margin, and the slope of the surface of the moved part is greatly diminished and in many cases reversed. Between the reversed slope and the limiting scarp a depression is thus formed which may become a pool. The change in the slope thus occasioned gives rise to the landslide terrace.[1] This kind of movement may be slowly continuous for considerable periods, or it may be fitful, depending upon the supply of water. In a slumping tract the movement may be repeated at various levels, giving the slope an irregularly stept or terraced profile; and if the movement has been recent, numerous cracks and fissures traverse these terraces, particularly where they break away from the upper limiting scarp.

The instability of the mass is an essential feature of the earth-slump. When not actually moving, its movement is imminent at all times, but with varying degrees of imminence, depending upon local conditions. This instability and imminence of movement is true of many slopes where no actual earth-slump has appeared, but where movement may be inaugurated at any time by an exceptionally heavy winter or by some other precipitating cause. Severe earthquakes constitute one of these precipitatory causes. Thruout the Coast Ranges of California the small residual stability of many earth-slumps was overcome by the vibration of the ground at the time of the earthquake of April 18, and they were caused to slump forward. In many other instances new earth-slumps were started, owing to the same general cause. Besides the earth-slump movements which were the immediate effect of the earthquake shock, there were doubtless others which were indirectly referable to the same cause. As will be shown in another part of this report, one effect of the earthquake was the derangement of the normal movement and amount of flow of underground waters, the general result being a temporary increase of flow. Inasmuch as many earth-slumps depend for their water upon springs, there can be little doubt that the increased flow had its effect upon these, and promoted their activity several days or possibly weeks after the shock itself.

Another way in which the shock conduced to the activity of earth-slumps at a later date than the shock itself was by opening cracks and thus rendering the deeper portions of the unstable mass more accessible to the rains of the following winter. The movement of earth-slumps at the time of the earthquake was abnormally large and sudden, thus leading to the development of numerous open cracks, not only in the landslide proper, but also in the surrounding slopes above the limiting scarp. The effect of this would inevitably be the enlargement of the area of the slide in the wet season. Similarly on many slopes, particularly at points not far distant from the Rift, numerous cracks were opened without actual slumping of the ground occurring in consequence of the shock; but the conditions were thus provided for the slumping process the following winter. During the winter 1906-1907 many such slides were reported in a general way. Unfortunately detailed information as to their occurrence is as yet lacking. It is to be noted that an exceptionally heavy rainfall conspired with the conditions established by the earthquake to produce these landslides.

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[1] See U. S. G. S. Monograph, I, Lake Bonneville, by G. K. Gilbert, p. 83.

In the type of landslide thus far considered, the contained water, which is at once in part the cause and the means of the movement, accumulates relatively slowly, and it varies with the season, there being usually a more or less free drainage from the lower portion of such slides. There are, however, other landslides which are due to a relatively large and sudden accession of water to the unconsolidated materials of a slope. Such sudden accessions of water may be conceived to be produced in a variety of ways; such, for example, as a so-called "cloudburst" in a desert canyon, the slopes of which may be heavily mantled by earth and loose rock; or the breaking of a barrier which retains a bog or other body of water. For the present purpose, however, which is not that of an exhaustive systematic discussion of this class of phenomena, it will be sufficient to take note only of water which is expelled from the ground by the compressive action of the earthquake shock. Such landslides may be discriminated from earth-slumps by reason of their greater mobility, under the designation *earth-flow*. Earth-flows differ from earth-slumps not only in the much larger quantity of water involved in their mechanism as a moving mass, in the suddenness with which the water becomes efficient as a transporting agency, and in the rapidity of the movement; but also in the brevity of the entire process, its finality, and its non-recurrence.

Besides these two types of landslides, there is still another, which is immediately associated with earthquakes as a cause of movement. This is the slide of dry earth and rock upon precipitous slopes or their fall from cliffs. Soil or other loose forms of earth may participate in such landslides, but the material is usually composed chiefly of rock which becomes increasingly shattered with the progress of the slide. Such landslides will here be referred to as *earth-avalanches*. They are distinguished from both earth-slumps and earth-flows by the character of the material and by the absence of water as an essential factor in producing movement. They also differ usually in the marked acclivity of the slopes on which they occur. They differ from earth-slumps, but resemble earth-flows, in the finality or completeness of the movement. They are not progressive movements, but sudden events; and there is no recurrence of movement of the material involved, altho the avalanche may recur at the same place.

Besides these three types of landslide, another ought perhaps to be recognized. This is the form of superficial earth movement which occurred in consequence of the earthquake shock on the alluvial bottom-lands of many streams. It may appropriately be designated an *earth-lurch*. It varies from the opening of a mere crack, with a slight movement of the ground on one or both sides, to a violent and complicated deformation of the surface, usually accompanied by cracks and open fissures parallel to the trend of the neighboring stream trench. These cracks and fissures cut the ground up into strips or prisms which lurch toward the stream trench, or, it may be, toward an abandoned slough, the lurch usually being accompanied by a rotation of the prism. They are distinguished from all other forms of landslides by occurring on perfectly flat ground and by the fact that they are apparently referable directly and solely to the horizontal jerk of the earth movement during the earthquake shock.

A brief account, which in some cases amounts only to a mention, will now be given of some of the various kinds of landslides set in motion by the earthquake.

EARTH-AVALANCHES.

Earth-avalanches were caused chiefly along the sea-cliffs of the coast on the morning of the earthquake, tho some also occurred on steep canyons within the zone of high intensity. On the coast the earth-avalanches were for the most part simply an exceptional incident in the normal process of cliff recession. Where the upland of the Coast Ranges approaches the shore, the horizontal corrasion of the waves maintains a steep sea-cliff; and the recession of the sea-cliff is effected by the repeated occurrence of earth-avalanches due to the undermining by the sea, combined with the disintegrating action of atmospheric agencies. There are thus always upon the face of the cliff masses of earth or rock, the fall of which is imminent and may easily be precipitated by a severe shock of earthquake.

The most notable of the earth-avalanches occurred where the sea-cliffs are highest and steepest. This happens on the coast of Humboldt County, between Cape Mendocino and Point Delgada. Not only are the cliffs here particularly favorable for large earth-avalanches, but the coast here is close to the line of the fault which caused the earthquake, and so received an exceptionally severe shaking. For many miles of coast there was a general slipping of rock and earth into the sea, down very precipitous sea-cliffs ranging up to over 2,000 feet in height. Between Shelter Cove and Point Arena, the sea-cliffs are not so high nor so continuous, but there was nevertheless a very general, and locally large, shedding of material from their face; and the sea was muddy for many days after the earthquake in consequence of the dejection of the débris upon the shore, within range of the attack of the waves.

From Point Arena southward to Fort Ross, the cliffs are low, being for the most part not in excess of 100 feet. Earth-avalanches were nevertheless of common occurrence along this stretch of coast. South of Fort Ross to Bodega Head the cliffs are again, as far as the mouth of the Russian River, several hundred feet high and very steep. Here again earth-avalanches were extensive. The rocks along this entire stretch of coast from Cape Mendocino to Bodega Head are prevailingly sandstones and shales. On the sea-cliffs on the north side of Bolinas Bay and west of the town of Bolinas, there was a very general crumbling and fall of the sea-cliff upon the beach. South of the Golden Gate, the most notable earth-avalanches were along the sea-cliffs between the city and Mussel Rock. This cliff has a length of about 6 miles and ranges in height from about 100 feet up to 700 feet, and is cut almost wholly in the strata of the Merced (Pliocene) series, which are inclined at angles varying from 15° to 75°. The rocks are for the most part rather soft and incoherent, tho there are numerous well-cemented and indurated beds in the series. This cliff converges on the fault at a small angle, and intersects it at its south end near Mussel Rock. The cliff was severely shaken and great quantities of earth and rock were caused to fall or slip down. The great earth-slump at Mussel Rock (Plate 129c, D) was also notably accelerated. A similar sudden movement of the ground occurred on the west side of Merced Lake, whereby a large section of the slope sank toward and into the lake, and a portion of the bottom of the lake was lifted above the surface by the deformational rotation of the collapsed ground.

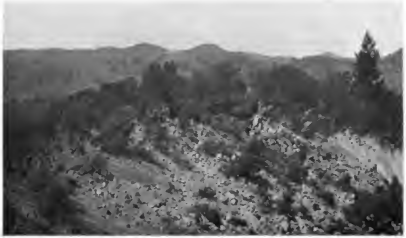
To the south of Mussel Rock there were several small earth-avalanches along the cliffs, and numerous cracks were formed near the brink of the cliffs which will in future doubtless lead to further falls from the cliff-face. Near San Pedro Point there was a large movement of the earth on the face of the high cliff. One earth-avalanche to the north of the Devil's Slide started about 800 feet above the shore and swept the face of the cliff, carrying away several hundred feet of roadbed. The slide occurred near the contact of sandstones reposing on granite, and both kinds of rock were involved. Smaller earth-avalanches occurred farther south on the sea-cliffs.

Inland from the coast there were numerous earth-avalanches caused by the earthquake on the walls of steep canyons. One of the most noteworthy of these was on the north side of a short but deep canyon west of Chittenden and close to the line of the fault. (Plate 126A.) The rocks composing the side of the canyon are the bituminous shales of the Monterey series. The slope rises very steeply for about 500 feet and was quite dry before the earthquake, altho it was covered with spring vegetation. Areas of bare rock appeared thru this vegetation. At the time of the shock several earth-avalanches were started, and these slid suddenly down the slope, part of the material filling the bottom of the canyon and part remaining on the less steep lower portions of the slope. The larger masses were broken off up near the brink of the canyon. There was apparently little or no rotation of the sliding mass. The result was to gorge completely the lower part of the canyon with rock débris, to widen the upper part of the canyon, and to expose extensive surfaces of unweathered rock.

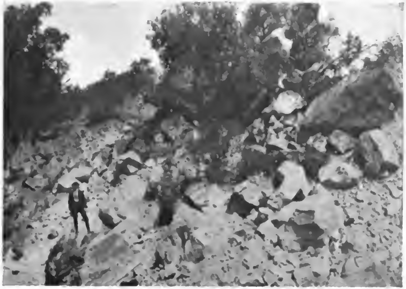
On Deer Creek, in the Santa Cruz Mountains, an extensive earth-avalanche started near Grizzly Rock and moved westward down a steep, narrow canyon for about 0.25 mile. (Plates 124D and 125A.) It then changed its course thru an angle of about 60° as it entered a wider canyon of lower grade, and following this for another 0.25 mile, finally stopt at the Hoffmann Shingle Mill, which was wrecked. A fine growth of redwood, some 200 feet in height, was mowed down, and covered to the extent of 10 acres or more with from 30 to 60 feet of débris. The trees were from 3 to 10 feet in diameter. The main canyon was filled with earth and rock for an average width of 80 yards and a length of 400 yards. The entire area of the slide was about 25 acres. The difference in altitude between the point where the slide started and the shingle mill, where it stopt, is 500 feet. According to Mr. G. A. Waring, the slide material has a depth of 300 feet and is composed of soil, clay, and shale. Mr. E. P. Carey, who examined and photographed this interesting earth-avalanche, states that it originated in rock that broke away in pieces from the steeply inclined slope at the head of the gulch, leaving a large theater-like space, the bare, light-colored rock walls of which were in sharp contrast with the surrounding green vegetation. The movement was faster in the center or deepest part of the gorge than on the margins. The rock was in general piled up higher along both sides than in the center, and many pieces became entangled in the standing or uprooted trees. A steep-walled tributary to the southeast of the main gulch supplied rock material to the main avalanche, and the 2 streams joined much as confluent glaciers do. The material involved in the avalanche showed every gradation from powder to angular pieces 30 feet or more in diameter. The surface was uneven thruout. Near the mill a man was killed by a tree that fell as the avalanche was advancing.

Mr. Carey also reports another earth-avalanche located on the Petty ranch, about 4 miles southeast of the one just described. Here a huge rock mass, which embraces an area of about 12 acres at the headwaters of Canley Gulch, broke away from a ledge and dropt, leaving a vertical scarp of 40 feet or more. The rock mass in this case was not shattered. It practically maintained its integrity. The narrow gulch below was unfavorable for free downward movement. As the block readjusted itself, its upper surface became nearly level, but was lower at the foot of the scarp than at its outer edge, thus indicating that it had suffered rotation.

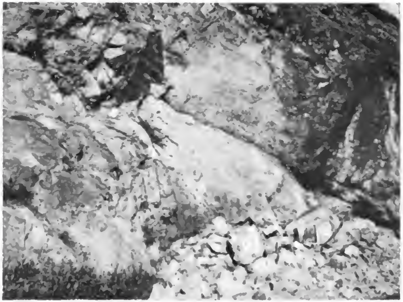
At a point about 1.25 miles west of the Mindego sink, on the ranch of Andrew Stengel, an earth-avalanche is reported by Mr. Albert C. Herre. It is on a small tributary of Alpine Creek, and about 4 miles southwest of the San Andreas fault at the point where the latter crosses Black Mountain into the head of Stevens Creek Canyon. The creek here is in a narrow, steep-walled canyon in the bituminous shale of the Monterey series. The soil on the canyon side was very shallow, and at the time of the earthquake it was shaken down into the bottom of the canyon, leaving the walls absolutely bare in places



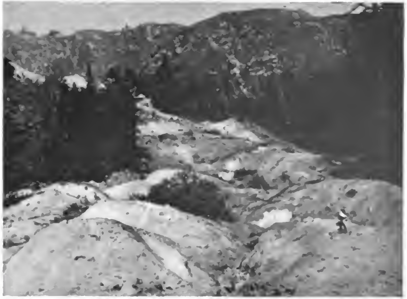
A. Maacama earth-avalanche. Tuffs dipping in the direction of the slide. Slip included the crest of the ridge. R. S. H.



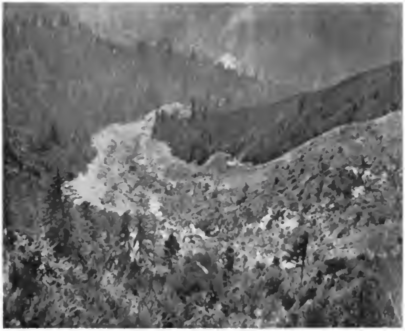
B. Maacama earth-avalanche. A close view. R. S. H.



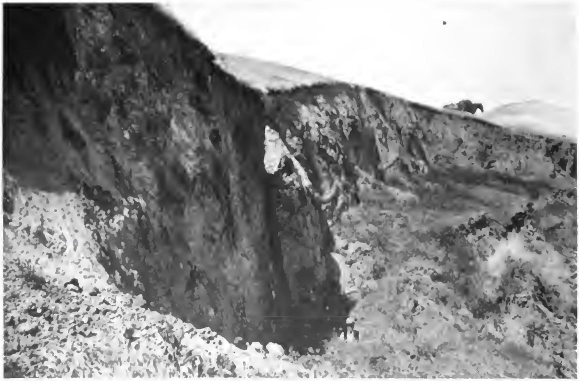
C. Earth-avalanche in granite on road near Half Moon Bay. E. D.



D. Deer Creek, Santa Cruz Mountains. Earth-avalanche from Grizzly Peak. B. B.



A. Deer Creek, Santa Cruz Mountains. Lower end of earth-avalanche shown in Plate 124 D. E. C.



B. Scarp of landslide in southeast quarter of section 15, township 16 south, range 12 east, near Cantua. G. D. L.

for a hundred yards at a stretch. The slide extends for 0.25 mile on both sides of the canyon. A similar earth-avalanche was caused by the earthquake on the ranch of Judge Welch, not far from Long Bridge and within 2 miles of Saratoga. Mr. Herre reports that here the soil on the northwest side of a small creek coming down from the Castle Rock Ridge, was shaken down for perhaps 0.5 mile, tho not continuously. In places the slid material filled up the creek-bed and totally changed the contour. It destroyed the road to the ranches farther up the canyon, and wrecked some bridges. Along the upper part of the area affected, a vineyard was destroyed; while farther down the canyon a heavy forest growth, consisting mostly of redwood, oak, alder, and laurel, was obliterated. This slide lies in the path of the San Andreas fault.

Mr. Herre further reports a large slide on the Mindego Ranch, 20 miles southwest of Palo Alto. Here, on the north side of Alpine Creek, a tract of some 50 acres sank at the time of the earthquake, with little or no apparent forward movement. The tract sloped to the south and west, and formed part of a great, open hill pasture, with trees and underbrush about the lower or creek side. The creek-bed itself is filled with a growth of Douglas spruces and other trees. The land, which before the earthquake was steeply inclined, is now comparatively level, the eastern and northern part having sunk perhaps 100 feet, while that on the west has sunk but 10 or 15 feet. The surface of the sunken tract was greatly seamed and cracked, and part of it was flooded, owing to the springs uncovered; but otherwise it was unchanged in appearance. There was no piling up of earth, nor sliding of one portion over another. A fence crost the tract, and the posts on it sank so that but a few inches protruded above the surface; while some Douglas spruces also sank several feet into the earth. A number of cattle were on the land at the time of the earthquake, but were uninjured. It was a work of great difficulty to remove them, block and tackle being necessary. The creek-bed was apparently not affected, nor were the trees in it disturbed. There was no apparent movement of the earth into the canyon, but the whole mass seems simply to have been dropt from a steep slope to a nearly uniform level, surrounded by the high, blank, almost perpendicular walls of earth and rock from which it had been sundered.

Many other earth-avalanches of minor importance were caused by the earthquake in various parts of the Santa Cruz Mountains. At Hidden Villa, 2 miles northwest of Black Mountain, large blocks of rock are reported to have rolled down the slopes. There were numerous slides along Stevens Creek, due chiefly to the caving of the creek banks. Along the ridge road southwest of Stevens Creek, sandstone blocks, some of them 6 feet in diameter, rolled down the hills toward the creek. Near Half Moon Bay considerable masses of granite were dislodged on a steep slope. (Plate 124c.) On the road along Pilarcitos Creek, an earth-avalanche brought down big blocks of sandstone upon the road. (Plate 126B.) At Boulder Creek a large portion of the soil was shaken loose from an abrupt hill 150 feet high, and fell to the level of the creek, carrying trees with it. At the north end of Ben Lomond Mountain, a slide carried trees and brush down to the creek. Near Olive Springs, 12 miles north of Santa Cruz, an earth-avalanche demolished Loma Prieta Mill and killed several men. At many places on the south side of Corte Madera Creek, huge masses of rock had been thrown down from the steep bluffs into the road, completely blocking it. About a mile from the summit of the ridge, where the Alpine road enters the Page Mill road, a slide carried away the entire roadbed for a distance of about 300 feet. On Purissima Creek a slide filled the road for a length of about 100 feet; another, between 0.25 mile and 0.5 mile long, dammed the creek to a depth of 25 or 30 feet. A large slide close to Wright Station partly dammed the stream. On the western slope of the ridge just west of Skyland, several earth-avalanches were caused by the shock; and great slides of a similar character occurred on both sides of Aptos Creek for 0.75 mile. Besides these, there were many smaller earth-avalanches in many parts of the Santa Cruz Mountains which can not be enumerated. There were also several such slides on the granite slopes of Montara Mountain, farther north in the San Francisco Peninsula.

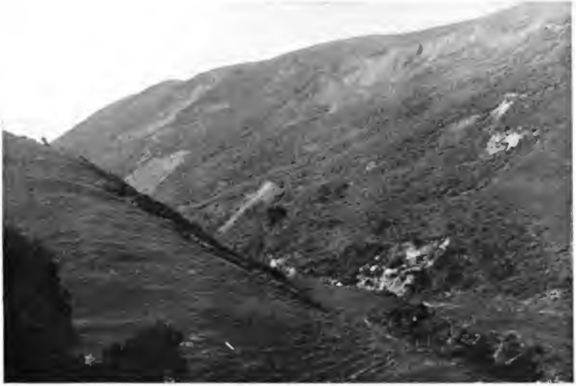
In the Coast Ranges to the north of the Bay of San Francisco, earth-avalanches were not so common away from the coast as they were in the Santa Cruz Mountains. There were, however, two notable ones which deserve mention here. The first of these is the Maacama slide, 6 miles east of Healdsburg. (Plate 124A, B.) The slide is about 0.125 mile wide at the top, and 0.5 mile long. The rock is a stratified volcanic tuff, and the slip was down the dip of the beds. The avalanche cut its way thru a fir forest and dammed Maacama Creek. The other is the earth-avalanche which, on May 1, 1906, dammed Cache Creek to a depth of 90 feet at a point 4 miles below the confluence of the north and south branches of the creek. The rock which fell is red sandstone. The width of the slide is 300 feet and its height is 500 feet. The dam thus formed broke one week later. This earth-avalanche can not be so directly referred to the earthquake of April 18 as the others heretofore described, but it was probably indirectly caused by the shock.

EARTH-SLUMPS.

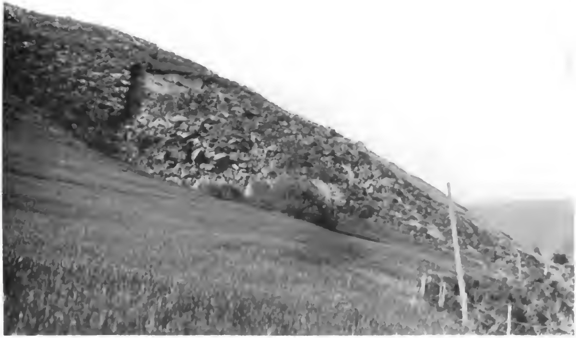
By far the most common manifestation of landslide phenomena was that here referred to as earth-slump. It would be wearisome to attempt to mention all the various earth-slumps stimulated by the earthquake, even if information were sufficiently detailed to make this possible. Only two of the more important slides which have come under the observation of geologists will be noted.

Cape Fortunas earth-slump (F. E. Matthes).—This landslide, immediately south of Cape Fortunas, is by far the most extensive one on the northern coast. (See plate 127A, B.) In May, 1906, it projected into the ocean for about 0.25 mile, like a hummocky headland of irregular outline; indeed, it formed a new cape on the coast-line, but will doubtless rapidly be cut back by the action of the waves. Its length, in the direction of its movement toward the ocean, is estimated at little short of a mile; its width varies from 0.25 mile to 0.5 mile. Its total descent, from the summit of the higher scarps at its head to the level of the sea, is probably less than 500 feet. Its surface is exceedingly irregular, with many large humps and hollows. Over large areas the sod is more or less rhythmically broken by deep cracks extending at right angles to the direction of movement. These cracks are only a few feet apart, and the sod-blocks between them lie mostly in tilted attitudes, making the area exceedingly difficult to traverse. The general aspect is not unlike that of a much crevassed glacier. In some places, however, the mass seems to have been torn apart so completely that the sod is not merely broken but almost swallowed up or buried, the browns and yellows of the under soil being the prevailing tints. Around its head are a number of steep scarps, from 100 to 200 feet high. They are especially prominent on the north side, and again toward the southeast; but over considerable stretches between these two sets, the broken surface of the slide joins the unbroken hillsides to the east without significant offset. Owing to this, the slide is easily approached from the wagon road (from Centerville to Cape Town), which passes close by its head. The longitudinal profile of the landslide is one of gentle slopes for the most part; its declivity is not at all great, and in a few places even reversed slopes occur. Its noteworthy feature is not its vertical drop but its great forward movement. In a sense it has flowed like a partially plastic mass, expanding and advancing 0.25 mile beyond the coast-line, but descending only a few hundred feet.

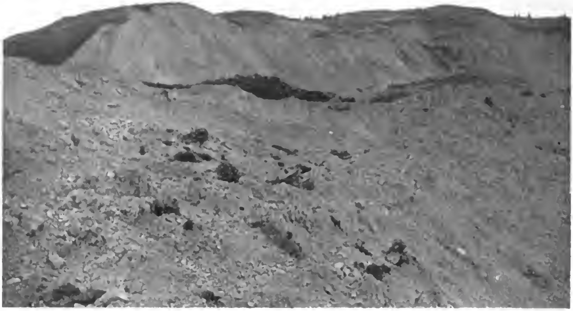
In its general aspect, as well as in the nature of its movement, the Cape Fortunas landslide is altogether different from those observed farther south, particularly along the mountainous coast both north and south of Point Delgada, which, in effect, did little



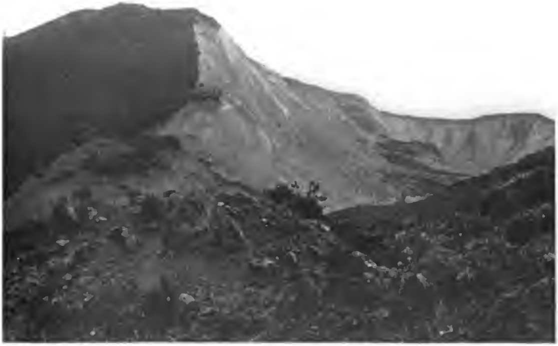
A. Earth-avalanches on side of canyon near Chittenden. A. C. L.



B. Earth-avalanche in sandstone near Half Moon Bay. Slip on bedding planes. E. D.



A. Earth-slump at Cape Fortunas, Humboldt County. A. S. E.



B. Earth-slump at Cape Fortunas, Humboldt County. A. S. E.

else than revive a series of old landslide facets. This may not be apparent to an observer on the beach, but is quite striking when the coast is viewed in its entirety from a vessel off-shore. These facets existed before this earthquake, and had been recognized as such. They are conspicuously outlined against the dark timbered slopes behind them, rising from 1,000 to 2,000 feet above the shore, and affording an important series of landmarks for the mariner. In strong contrast with these bold mountain forms is the region in which the Cape Fortunas landslide took place. The land here can scarcely be called mountainous; and while it breaks off in cliffs at the coast and is traversed by many fairly deep draws, it is essentially a region of subdued relief. Great declivities are notably absent, except in the sea-cliffs, and even these are only a few hundred feet high. At the same time, evidences of former landslides may be seen on every hand. They are not extensive, as a rule, and are as likely to occur on gentle slopes as on steep ones. In a few cases only is a marked downslip noticeable, resulting in the uncovering of a steep scarp; in nearly every instance the dislocated mass appears not so much to have sheared off and dropt from its former position, as to have expanded or slumped, with an accompanying subsidence of its surface. The billowy and irregularly pitted appearance of these areas, together with the rank vegetation that covers them, afford the principal marks of identification. Both from their characteristic form, suggestive of plastic flow, and from their mode of occurrence, it seems reasonable to infer that ground-water plays an important rôle in their genesis. They are apparently masses which have changed their shape in obedience to a lessening of cohesion in their interior, through saturation with water. Whether the movement be initiated by an earth-tremor or not, it is in every case essentially an adjustment to a more stable position, rendered necessary by a change in the physical constitution of the mass.

It is to this category of landslides that the one at Cape Fortunas belongs. While there are scarps in various places at its upper end, these are really insignificant features alongside of the extensive tract of the slide itself. What downslipping occurred on these scarps was merely an incident in the entire movement. Both in the large ratio between its horizontal advance and its vertical drop, and in its general appearance, the Cape Fortunas landslide is closely analogous to the numerous lesser slides referred to; and there is good reason for the belief that, like them, it consisted essentially of an adjustment of equilibrium in a partially water-saturated mass. It probably had long been imminent before the earthquake started it.

San Pablo earth-slump. — At the time of the earthquake a landslide occurred on Mills' ranch, which is about 4 miles east of San Pablo. The slide is interesting from the fact that a previous geological mapping of the region indicated that the point where it occurred was on the line of a fault extending in a northerly and southerly direction through the Sobrante Hills. The slide was examined by Mr. E. S. Larsen, who describes it as follows:

> There are many other landslides in this vicinity, showing that the country is subject to such slides. In this particular case, one of the Castro boys informed me that the main part of this slide began during the winter rains, and had fallen a foot or more during these rains. The balance of the fall occurred the morning of the earthquake. The slide is on the east slope of a steep hillside and extends from the top of the hill nearly to the bottom, about 400 feet on the slope. The width is about 1,500 feet. At the northeast corner the scarp is greatest, reaching perhaps 50 feet. It gradually decreases, and is very slight for the southwest 700 feet. On this southwest 700 feet the only evidence of a slide is the crack near the top of the hill. The north 800 feet of ground shows every evidence of sliding. The dry ground is much cracked, and these cracks extend up and down the hill near the scarp and along the hill where the ground has been piled up. In some places there is a network of cracks. On the south side of the main slide the ground has piled up about 10 feet. This extends along nearly all of the south side, and this tendency to pile up to the south is shown in other places. Moreover, the north side shows that the ground has pulled

away toward the south. The above shows that the movement was not directly down the hill, but was more to the south. The formation is sandstones and shales, with considerable soft surface soil.

The same slide was subsequently visited by Mr. F. E. Matthes, and the following descriptive note is by him. (See figs. 68 and 69.)

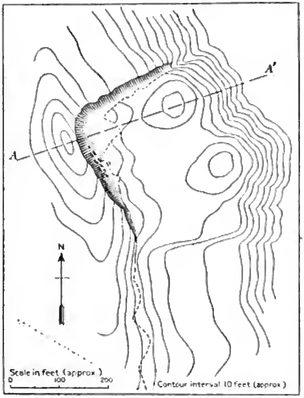


FIG. 68. — Map of landslide caused by the earthquake east of San Pablo.

The slip occurred east of a high ridge at the southern end of the Sobrante Hills. It covers the northeast half of an area whose terraced nature is indicative of a former landslide of much larger dimensions. The accompanying sketches show the general outlines, and a cross-section of the slide. It will be noticed that the slide does not extend all the way down the slope, its lower edges being fully 100 feet or more above the bottom of the gulch. The lower slopes were not materially changed, and but little débris fell into the stream-bed.

A steep scarp has been produced east of the crest of the ridge. The downslip along this scarp does not exceed 50 feet, and decreases both to north and south. Along the north edge there has been a marked movement down and southward, the scarp there averaging 10 feet. Along the south side, on the other hand, the loosened mass had advanced over the old surface, presenting a bulging and cracked frontal scarp some 6 feet high. It appears from this that the movement took place, not along the line of greatest declivity, but in a direction somewhat more southward, as indicated by the arrow. The 2 hummocks probably existed before the slip occurred, but judging by their greatly cracked and rent surfaces, it seems likely that their height has been slightly increased. The main crack, which extends southward from the upper scarp, continues along the hillside in irregular zig-zags for some 300 feet south of the slide. (See plate 128A, B.)

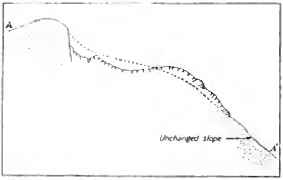
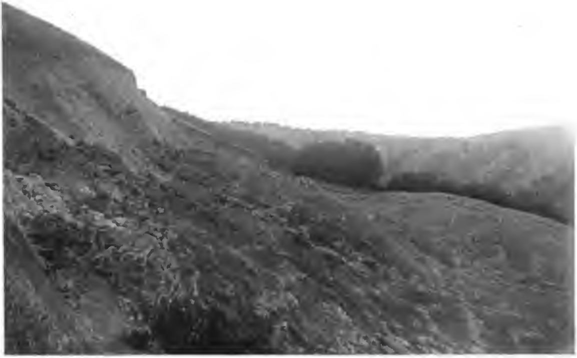


FIG. 69. — Section of landslide shown in fig. 68, along the line A–A'.

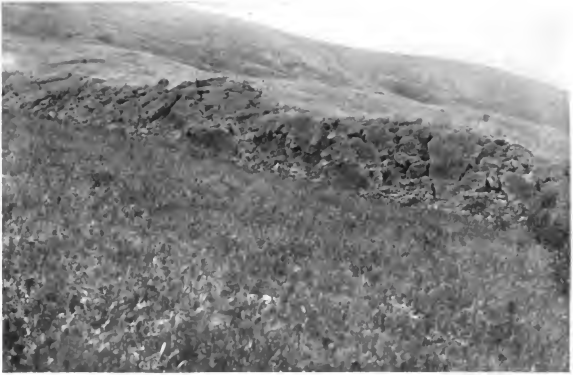
Other earth-slumps referred to under the section on the Distribution of Intensity are shown in plates 125B and 129A, B, C, D.

EARTH-FLOWS.

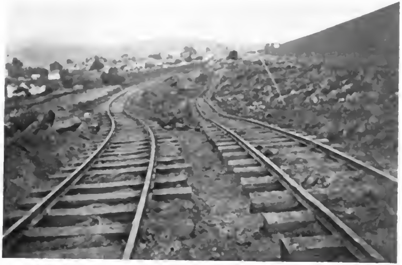
Mount Olivet Cemetery (A. C. Lawson). — Perhaps the best illustration of an earth-flow caused by a sudden accession of water to the incoherent materials of a slope, in consequence of the earthquake shock, is that which occurred in the upper part of Mount Olivet Cemetery, near Colma, 9 miles south of San Francisco. The locality is at the base of the San Bruno scarp, and about 2.75 miles northeast of the San Andreas



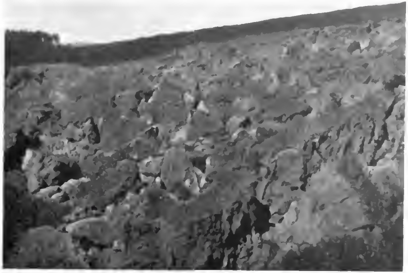
A. Earth-slump east of San Pablo. F. E. M.



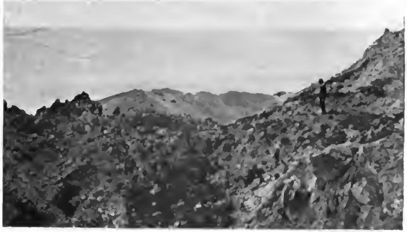
B. Earth-slump east of San Pablo. F. E. M.



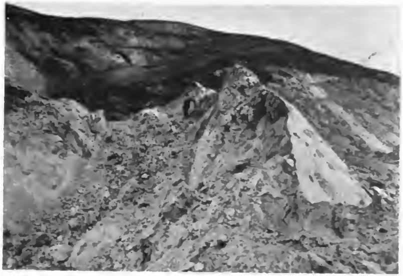
A. Earth-slump north of Tomales, carrying railway roadbed with it. Track was straight before earthquake. R. S. H.



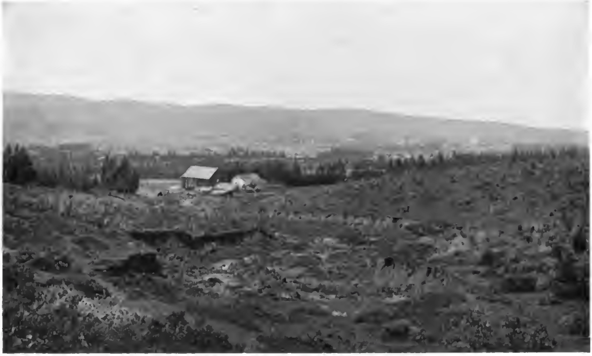
B. Earth-slump 3 miles northeast of Tomales, at Freeman's. R. S. H.



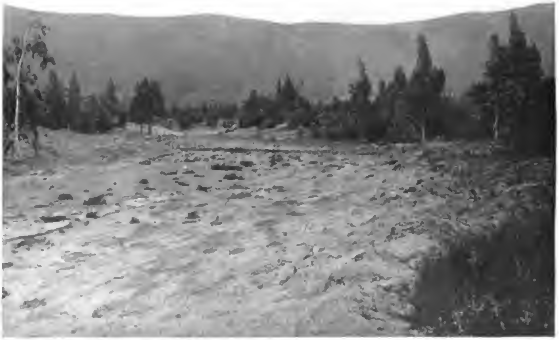
C. Earth-slump at Mussel Rock. Old slide suddenly accelerated by earthquake. C.



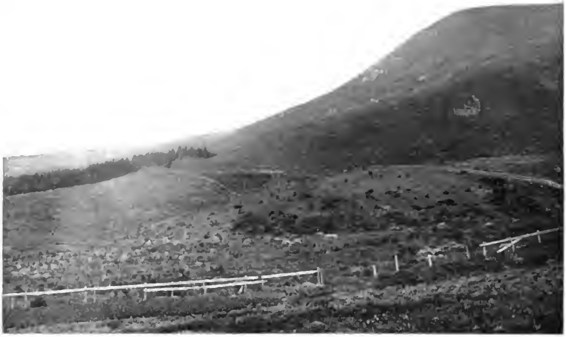
D. Scarp of Mussel Rock earth-slump. C.



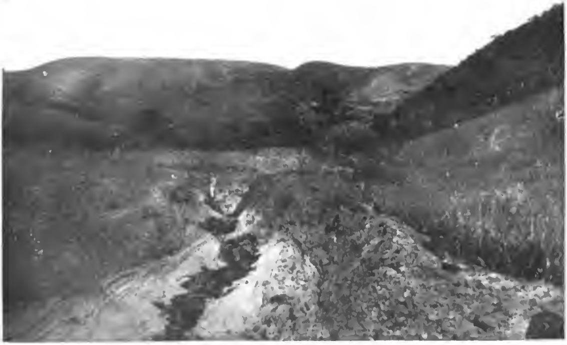
A. Earth-flow at Mount Olivet Cemetery. Source of flow, looking down. A. C. L.



B. Earth-flow at Mount Olivet Cemetery. Path of flow, looking up. A. C. L.



A. Earth-flow, Mount Olivet Cemetery, at base of San Bruno scarp. Looking northwest. A. C. L.



B. Earth-flow in hills east of Half Moon Bay. R. A.

fault at Mussel Rock. The steep slope of the scarp is underlain by hard sandstone of the Franciscan series, with but a thin veneer of soil, or none at all. At the base of the scarp is the gentle slope of Merced Valley, underlain here by Pleistocene and recent sands. The sands, partly eolian, lap up on the lower flanks of the scarp, and mantle the trace of the auxiliary fault which follows its base. The sands thus vary in thickness from a feather edge to an unknown thickness, which it is believed may be as much as a few hundred feet at no great distance from the base of the scarp. Traversing the gentle slope of the valley-floor are several shallow arroyos, which head in incipient ravines in the face of the scarp. At the moment of the earthquake there was a sudden outgush of sand and water at a point at the upper end of the cemetery, close to the base of the scarp and quite near, if not immediately upon, the line of the buried fault-trace. This stream of sand and water, admixed with the loam of the slope, flowed rapidly down the course of a shallow arroyo on a grade of about 1:25 with a depth of from 13 feet in its upper part to about 3 feet in its lower. The front of the stream stopt abruptly at a point just beyond the roadway about half a mile from the origin. The flow was so rapid that it carried away many small trees; a wind-mill was wrecked and the heavy concrete blocks which served for its foundation were swept down, with other débris. One of the pumping stations of the cemetery was demolished by it, and 2 horses were carried off their feet, and were extricated afterwards with difficulty. (See plates 130A, B and 131A.)

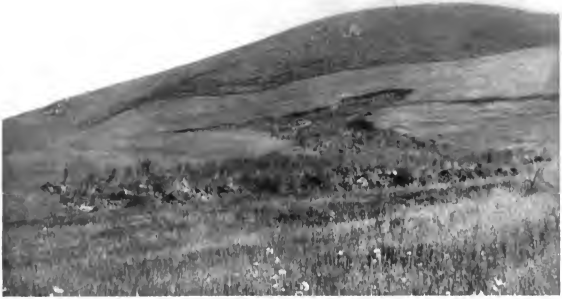
According to Mr. M. Jensen, the superintendent of the cemetery, the entire flow had been accomplished within 3 minutes from the time of the shock, and he was at its source within 20 minutes after it occurred. The height of the flow within a few hundred feet of its source was attested by the mud upon the trunks of some eucalyptus trees near its margin. This mud extended up to 13 feet above the bottom of the arroyo. This, however, doubtless indicates the height of the front of the stream as it past this point. As the flow advanced, its surface near its source rapidly dropt; and by the time the front had reached the roadway the stream was probably no deeper at its source than at its terminus. Indeed, it seems to have been somewhat less, as there was a marked tendency for the sand to pile up at the front by reason of the negative acceleration at the front due to loss of water. After the moving mass had come to rest and partially dried out, it was found that it had left a streak of muddy sand on the bottom of the arroyo averaging 100 feet wide and about 3 feet thick. Taking the length of the flow as 900 yards, this gives the total volume of the compacted wet sand as 89,100 cubic yards. The cavity in the slope caused by the evacuation of this sand and loam was not measured, but was estimated to have a width of 150 yards, a length of 300 yards in the direction of the flow, and an average depth of 2 yards. On this estimate, its volume would be about 90,000 cubic yards, which agrees quite closely with the estimated volume of the material ejected.

The sand, after it had ceased flowing and had been drained and compacted, undoubtedly held in the voids between the grains not less than 25 per cent of its volume of water. An additional 15 per cent would probably give it the necessary fluidity for flow down a slope of 1:25. But as the flow was swift, there was an excess of water, so that probably 25 per cent would have to be added to give it the properties manifested in the actual flow. The sand, however, in its original position before the time of the earthquake, probably did not contain more than 20 per cent of water, since the upper or soil layer had been somewhat dried out by the air. To the original sand of the slope, therefore, there must have been added 30 per cent of its volume of water to cause it to behave as it did. This amounts to 27,000 cubic yards. This water came from ground immediately below the source of the flow; and it came in a moment, at the time of the earthquake. It is only another way of stating the facts to say that it was squeezed out. There was no disturbance of the soil on either side of the cavity, even in its immediate vicinity. On the shoulder to the southeast, where the trace of the auxiliary fault passes over practically bare rock, no evidence of movement was detected on critical examination. The expulsion of the water was a purely local phenomenon. In attempting to explain the cause of it, or to ascertain the local subterranean conditions which conspired with the earthquake shock to bring about the event, it should be noted first that on the line of the fault-trace there are longitudinal depressions, which appear to be in part structural and in part due to erosion following the fault. If one of these depressions should locally have the character of a sink, without free drainage, then the sand which filled it would be saturated with water in consequence of the rains of the previous winter. It is believed that the compressive action of the earth-wave passing through such a pocket of saturated sand, and reflected perhaps more than once from the containing rock walls, would be adequate to expel 27,000 cubic yards of water from the deeper portion and add it suddenly to the more superficial portion of the formation, thus bringing about the earth-flow. It may be stated in this connection, although it has no conclusive bearing upon the question involved, that the sands of the valley generally are an abundant source of well water, and that there is a surface well within a few hundred feet of the source of the earth-flow, lower on the slope. There was very little water in the arroyo before the earthquake and a very insignificant stream afterwards, the latter being probably referable to the drainage from the ejected sand.

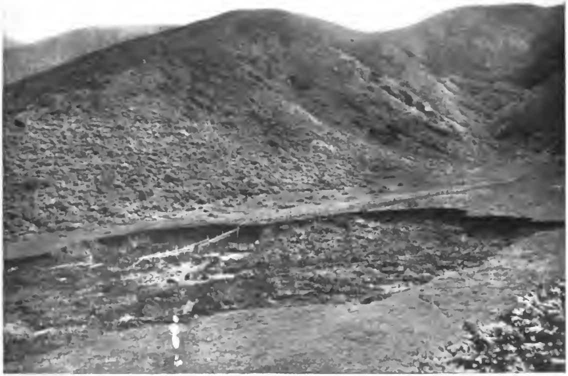
Vicinity of Half Moon Bay (Robert Anderson). — The earthquake shock caused the appearance of an unusual amount of water at the surface in many places. This was noticeable in the vicinity of San Bruno, where several short streams running into the bay were flooded by an unusual volume of water during the first days following the earthquake, in spite of the fact that it was perfectly clear weather. Instances have been cited in the present writer's notes on the results of the earthquake in the San Francisco Peninsula, of water with a salty taste or milky color issuing from springs after the shock, and of streams being muddy and flowing with increased volume. These facts, and the fact that water continued to issue after the earthquake at the points where earth-flows occurred, and where it had not been in evidence before, and that earth-flows occurred sometimes on convex slopes where the concentration of water under normal conditions would be unlikely, seem to be explainable only by the theory that underground conduits were disturbed and made more open, that new channels of escape for the water were formed, and that water was actually squeezed out of the hills in some cases by compressive movements. This flowage of water to the surface, in increased amounts and sometimes at new places, caused the formation of the earth-flows. The places where these debacles occurred may or may not have been previously points of concentration of seepage water, and the soil already in part saturated. But it is supposed that the content of water was increased by the shock, possibly in extreme cases by the gushing up of a large volume; and that this increment of water, with its disintegrating, weighting, lubricating, and direct forcing power, aiding the attack of the shock on the soil, was the main cause of the earth-flows.

There is little evidence as to when the flows were first set in motion; whether at once during the shock, or later after the lapse of some brief period of time that may have been necessary for the accumulation of the water in extra large quantities.

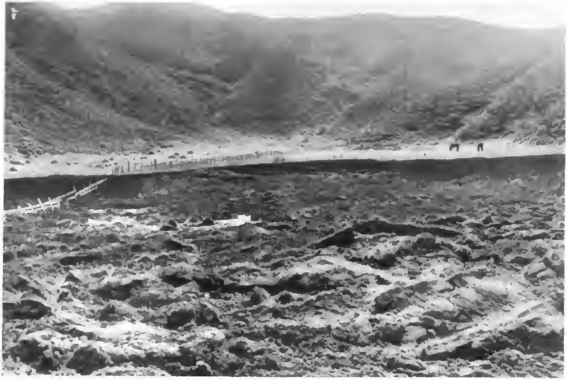
Earth-flows originated in valleys, in gullies, or on hillsides. Where the weight of the earth, combined with the weight of the added water, was sufficient and the substratum of the soil was rendered plastic, gravity caused it to creep like a lava-stream, leaving a hollow in the place from which it came and a fan or tongue of débris down the slope below. Movement was especially apt to ensue where the ground had been previously wet, the intensity of the earthquake shock being particularly great at such points and



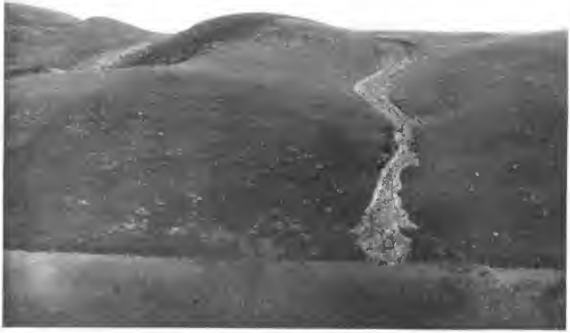
A. Earth-flow in hills east of Half Moon Bay. R. A.



B. Earth-flow in small valley near Half Moon Bay. R. A.



A. Earth-flow shown in Plate 132 B, illustrating floor of cavity from which flow came. R. A.



B. Earth-flow 4 miles east of Half Moon Bay. R. A.

the tendency of the vibrations being to set the mass in motion. Earth-flows occurred in many places in the Coast Ranges, and probably thruout the region in which the shock was heavily felt. The writer found many of them, large and small, on the San Francisco Peninsula and in the Santa Cruz Mountains, also in the Mount Diablo and Mount Hamilton Ranges.

Following are descriptions of 5 earth-flows that occurred on the morning of the earthquake in the neighborhood of Half Moon Bay, which is on the coast 25 miles south of San Francisco:

One of them was formed in the hills bordering the terrace at Half Moon Bay, immediately south of Frenchman Creek, 1.5 miles north of the town, and a mile from the sea, at an elevation of 100 feet. It is pictured in plate 132A. At this place the earth caved away in a crescent-shaped area on a slope of only 18°, and flowed out in two long arms so as to leave a hole 4 feet deep, surrounded by vertical walls of unaffected soil. The flow occurred at a fairly high point on a gently undulating incline. The discharged earth was divided by a mound, at a point 150 feet below the summit of the arc, and followed two courses which were determined by gullies on both sides. Much of the débris overflowed the central mound at the same time, and inundated the barley fields to a depth of 2 to 4 feet, for 100 feet farther. On both sides of the central mound the caving away continued to the same depth. In the left-hand fork it stopt within a few feet, and the flow did not extend very far beyond. In the right-hand fork a cut 100 feet long and 50 feet wide was made, the earth flowing down from it 250 feet farther over the grain field, as shown in plate 132A. Thus the whole length of the slide was 500 feet. The width of the main hole was on the average about 100 feet, and the length, as already mentioned, 150 feet not including the arms.

In this hollow in the hillsides many dry blocks of sod carrying growing grain — usually in an upright position — were left stranded 4 feet below the surface of the hill by the removal of the subsoil. The fence that crost this area was broken and carried away and partly buried. Where the caving ceased in the right fork, a ridge of débris was piled up across the mouth of the hole, much higher than the stream of loose material that flowed farther. Similar ridges were heapt up across the path of the flow, where the breaking away of the hill stopt in the other arm and at the upper end of the central mound.

The south or right arm of the flow extended down the hill at an angle gradually decreasing from 18° to less than 5°. Large parts of the fence were carried on its surface for 300 feet.

Plate 132A gives a detailed view of the lower extremity of the right arm. The stream came to an abrupt stop, like a quickly cooled lava flow, and preserved a face 1 to 2 feet in height above the grain field. The surface of the flow consisted largely of blocks of sod, usually almost upright, which were carried down from the hole without much moistening, or transformation into material capable of flowing. The bulk of the flow was a moist aggregate of earth fragments possessing something of their previous form and grading into mud, which assumed a semi-fluid consistency underneath. The bottom of the hole, and the flow itself, remained too muddy to walk on for weeks after the earthquake, and the field below the lower end of the large arm was left marshy, tho it had not been so before. It is to be noted that several fairly heavy rains followed the earthquake after an interval of several days, and before these earth-flows were visited; but these were not sufficient to account for the amount of moisture observed. The chief effect of the water was in the ground at a depth of 3 or 4 feet below the surface. It rendered the soil sufficiently fluid to enable it to flow down the gentle slope, probably partly oozing from under the surface crust and partly transporting the sod with it. Most of the surface was carried down with the main flow, the stranded surface blocks that remained in the cavity being accountable for as fragments from the broken edges subsequently giving way and being carried only a short distance as the upper end of the flow came to rest. In this way, probably, the walls were trimmed, for the cut in general was left remarkably clean.

Another flow of similar character took place 3 miles north-northwest of the town of Half Moon Bay, on the creek next west of Frenchman Creek. It is shown in plates 132B and 133A. On the morning of the earthquake an acre of the gently sloping alluvial floor of a broad, short valley tributary to the main creek on the east caved and flowed out, leaving an excavation 10 feet deep, where before it had been almost level and where there had been no stream channel. In this case, the water already gathered in this basin-like valley, which here had had no means of prompt escape, was an important aid in the formation of the flow, aside from the sudden accession of water that probably caused the earthquake. The presence of a large amount of water and the forcible movement during the earthquake shock resulted in the loosening and undermining of the ground and its transportation as a fluent mass. The angle of slope was about 5°. The flow carried out thousands of tons of earth in this manner and spread it over about 2 acres of meadow land, to an average depth of 1.15 to 3 feet.

Plate 132B gives a view of this earth-flow, showing the pit from which it was derived. Covering much of the surface of the flow and the floor of the hole are to be seen blocks of sod which have been carried right side up as if the material had moved *en masse.* The amount of water in evidence shows clearly how the earth was softened and enabled to move. The picture was taken two weeks after the earthquake. At that time water was still seeping up from underground, and out of the lower portions of the broken walls, while the ground near the surface of the valley was quite dry. The water had formed two definite rivulets thru the débris, at an elevation above the surrounding meadow, and was running in continuous streams, fast cutting a channel for itself and removing the soft material. Considerable water was dammed back in the hole by a 4-foot ridge of débris piled across the mouth of the hole, as in the case of the previously described earth-flow. This mound of earth, along the line where the stream left the caved-in area and flowed over the preexisting slope, was probably piled up at the last by the remnants of the flow gliding down and heaping themselves up as a barrier at the mouth of the hole.

The cavity, about an acre in extent, has 10-foot walls which gradually decrease in height lower down the valley, the bottom of the hole being more nearly level than the valley-floor. Plate 133A shows part of this flow in detail.

Some of the great blocks of sod around the edges have not been removed, altho the material from underneath has gone. Concentric cracks not visible in the pictures extend around the edge of the hole and for 50 feet above its upper end, showing that the area affected is broader than appears at first sight, and that the work is not yet all accomplished. The material of the valley-bottom is a coarse, arkose earth, derived from decomposing granite, and containing many rock fragments.

A flood of earth covers about 2 acres of the meadow. Water was present in this earth-flow in greater amount than in any other that was examined. The nature of the material may be judged of by the abrupt face of the stream where it stopt. The edge makes a steep angle with the meadow and rises to an average height of 2 feet above it. Yet the fact that this mass of earth was able to move more than 300 feet after it left the lower end of the hole, and spread into an even and thin layer over a wide extent of nearly level meadow, shows that it was fairly soft. It was moved on a basal layer of semi-fluid mud and sand, with the aid of the weight of the overlying and partly disintegrated earth.

The largest of the earth-flows seen occurred in the canyon south of the house of Mr. Nunez, 2.5 miles east-northeast of the town of Half Moon Bay, at an elevation of about 500 feet. It originated in a manner similar to the others, but in a canyon along which there is a distinct but ordinarily dry stream channel. A long, irregular hole from 4 to 7 feet deep was excavated near the head of the valley, and a great volume of earth flowed down its curving course for 0.25 mile, as far as the Nunez house, and there stopt, being in part diverted into the main creek to which the valley is there tributary. According to the testimony of witnesses, the flow reached the end of the 0.25 mile in 0.5 hour after the earthquake shock. It was seen gliding slowly down and engulfing the orchard just back of the house. According to observers on the Nunez ranch, the earth-flow was not accompanied by any water; but two weeks later, when examined by the writer, it preserved every evidence of having been muddy. Especially was this true at the bottom, where great masses of mud still had the consistency of jelly. It is probable that there was no flowing water on the surface of this or other earth-flows at the time of their formation, and that the presence of water in the flow was not evident to the casual observer because of the comparative dryness of the material on its upper surface.

The slope of the canyon down which the moving body of land crawled is about 25° near the head and decreases to 15° farther down. The flow filled this to a width of 100 feet on the average, and to a depth varying from 10 to 20 feet. The inertia of the mass is illustrated by the fact that in the early stage of the flow the earth was piled 20 feet higher on the hill, on the inside of the big curve made by the canyon, not far below the pit, than it was when the flow came to rest. The marks at this elevation were probably made very soon after the main mass was discharged from the cavity, before it had spread very widely. The central portion of this earth-flow is pictured in plate 131B, where it appears as a ridge many feet high rising above the tall grass on the hillside, on the right of the picture. The pressure of the material at the head of the flow, as it started, was so great that the earth bulged up over the sides in places, in such a way as to force upward great blocks of sod and turn them on edge or completely over, away from the rim of the hole.

The flow assumed the form of two lateral ridges and a central depression, or channel. The ridge on the west or inner side of the curve was considerably the higher. The form was due partly to the concavity of the valley; but chiefly, it is thought, to the tendency of the more fluid material to follow the deepest possible path along the gully under the center of the flow. Thus the drier material was retarded at the sides. Subsequent to the first starting of the flow, a stream of semi-fluid mud and sand continued to run down the central channel, covering its sides with a coating of mud and leaving flowage striations on it. This channel and its markings are exhibited in plate 131B. Two weeks after the earthquake, when the photograph was taken, water was running in this channel and had cut down into it several feet deeper. Its bottom, however, was still from 5 to 10 feet higher than the bottom of the underlying preëxistent water course, where water had not flowed before at this time of the year. The man in the picture is standing at the bottom of the gully. To the left of him, the hammer and note-book mark the top of one of the parts of the lateral ridge which is here divided into several hummocks. To the right is the other and higher lateral ridge. The foreground was formerly covered by a dense thicket of willow trees. These willows have been completely buried, except at the sides where some dead branches protrude. A fence that crost the canyon was torn away for 100 feet, and not a trace of it could be found. The fence shown in the picture is one newly built in its place.

Two other smaller earth-flows occurred just over the hill westward from the last one described. They are shown in plate 133B, the canyon on the left being the one occupied by the Nunez flow. One of these 2 earth-flows, that at the right of the picture, started near the top of the ridge in a depression in the slope, formed a hole 75 feet long and 40 feet wide, and coursed down a narrow runnel having a gradient of 25° to the bottom of the hill, a distance of 600 feet. Enough earth issued to fill up the rather deep ditch in the gully clear to the bottom of the hill and to bury the grain field on both sides to a depth of 1 to 2 feet. In this case, as in the preceding one, there were formed lateral ridges higher than the center, so as to leave a groove between. Down this channel there flowed softer material, which lined the sides of the lateral ridges with a smooth coat of mud and left conspicuous flowage marks. The flow thus raised a ditch for itself above the level of the slope. The earth-flow probably assumed this form by leaving behind, at the sides, the material least capable of flowing, and by concentrating its most liquid parts along the deep central line.

The other earth-flow was near by, on the convex face of the knoll in the center of the picture. A similar cavity was produced, from which the contents were spread out broadly. It is a good example of the starting of a gully, as there was no depression before. One branch of this earth-flow came straight down the hill and slightly toward the canyon on the left; the other branch came down toward the gully in which the first-mentioned of these 2 earth-flows occurred. Thus drainage lines were started which ultimately may separate the central hill from the ridge on the right, of which it is now a continuation. The left arm of the flow on the hill may develop a channel, as explained below, which will cause the drainage from this hill, which is now toward the foreground, to pass into the canyon on the left.

Similar landslides, tho usually of smaller size, occurred thruout the region neighboring the fault visited by the writer, and even in districts at a considerable distance from the fault. Frequently they were not definitely referable to the earth-flow type, but resembled more closely earth-slumps formed without the aid of a suddenly increased water supply. It was often difficult, especially in cases where the movement was slight, or the slide was in the embryonic stage, to determine whether the earthquake at those points had caused a flow of water or not. In the instances so far described, it was pretty certain that it had; but in many others the phenomena were explainable as being the result of moisture that was already collected before the earthquake. Many slips were formed on hillsides and along the embankments of mountain roads, and along the cracks formed by the shock in moist and loosened soil. Often these slips were arranged one above another, the perpendicular faces due to slipping having the appearance of step faults. In such cases the weight of the moved mass and the amount of water was not sufficient to cause the material to flow. There were examples of such slips along the coast hills north of San Pedro Point, near the road halfway between San Bruno and San Andreas Lake, near the road from Belmont to Crystal Springs Lake, 0.5 mile southeast of the San Mateo Alms House, and in many other places on the San Francisco Peninsula. In some places bare ridges had their lines of symmetry broken into little knolls and irregularities by these slips, a common occurrence in the hills of soft sand formations in the northern part of the San Francisco Peninsula. All the slips just referred to illustrated the gradation between earth-slumps and earth-flows. Doubtless in many of them a small amount of water did gather as a result of the earthquake.

Relation of earth-flows to rainfall (Robert Anderson). — The rainfall previous to the earthquake, tho possibly of little importance in connection with the more extreme types of earth-flows, in which practically all the work was done by a head of water brought from underground by the shock, bears a close relation to the less extreme types, and to the geologically very important doubtful types intermediate between the earth-flows and earth-slumps. In a dry year the number and size of all of these would probably have been much less. Had covering of slopes been unsaturated, areas might not have been so ready to break forth at a sudden accession of water from below; and the rainfall not having been great, there might not have existed such a plentiful source of underground water to be drawn from. The following review of the rainfall conditions may be of value in indicating a relation between the preparedness of the ground and the number and importance of flows and slumps.

During the first three months of 1906 the rainfall was exceptionally heavy thruout California, being on an average thruout the whole State more than 9 inches in excess of the normal for that period. Up to the beginning of 1906, the amount of rain for the season was 4.5 inches below the average; but owing to the great excess during the late winter and early spring months the total for the year up to the first of April, the month in which the earthquake occurred, was nearly 5 inches above the normal. During January, February, and March the rain was heavy and continuous. Nearly all the rain of the season was during these months immediately preceding the earthquake month. Practically no rain fell between April 1 and April 18.

All of the rainfall data available in the monthly reports of the Weather Bureau for California, compiled by Professor McAdie, has been used for calculating the amount of rain in 8 counties south of San Francisco. These are San Francisco, Alameda, San Mateo, Santa Clara, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara. The average rainfall at 46 different places distributed thru these counties was 22.59 inches from September, 1905, to April 1, 1906, between 2 and 3 inches above the normal for this region. The excess would have been greater but for the lightness of the rainfall during the autumn term, which was 3.55 inches, or several inches less than the average for former years. During the spring season up to April 1, the precipitation was excessive. During the three months that preceded the earthquake, 19.04 inches of rain fell, or 84.30 per cent of the whole precipitation up to that time. During the first half of April, there was practically no rain at all. Thruout this region, as well as thru California as a whole, March was a very rainy month; especially heavy downpours coming everywhere in the State during the last days of the month. It was the rainiest of the months except in parts of Santa Clara and Santa Cruz Counties, where more fell in the month of January.

The majority of the earth-flows and earth-slumps that occurred were near the coast, although the amount of rain that fell was not as large there as it was farther back in the mountains. The coast region, however, is subject to heavy fogs, which precipitate some moisture and help to prevent evaporation of the moisture already present. These fogs were probably a factor in causing the earth-flows and earth-slumps near the sea. The principal cases described were near Half Moon Bay. The records from Point Montara, only a few miles away, showed that the rainfall in this vicinity was heavier than at any other point along the coast south of San Francisco. During the spring season up to April 1, it amounted to 23 inches, and during the autumn season it amounted to 12 inches. The table shows that the heaviest rains were in the Santa Cruz Mountains. At Boulder Creek, in Santa Cruz County, 55.70 inches of rain fell during January, February, and March alone, and 16 inches fell during the four months preceding.

During the spring of 1906, a large part of the precipitated moisture remained in the ground, which was previously dry, and the amount of evaporation was minimized by the continuous succession of cloudy and rainy days. The year afforded an example of the concentration of an excessive annual rainfall into a short period, with all the conditions favorable for the absorption and retention of the moisture in the ground. For this reason, conditions favored the production of debacles of various kinds in the loose material covering slopes.

The earth-flows that have been discust are more or less similar to the flows occasioned by the bursting of peat-bogs. The causes of their origin and their nature appear to be much the same.[1] Sir William Conway has given an account of a mud-avalanche,[2] a swift torrent of mud, water, and great rocks, in the Himalayas, somewhat similar in nature to these earth-flows. Streams and torrents of mud somewhat analogous but usually of glacial or lacustrine origin have been known to flow in the Alps. Mention of these has been made by T. G. Bonney.[3]

Earth-flows are important as giving rise to new drainage lines and modifying old ones. They are also powerful transporting agents. The initiation of a new drainage line is a matter of importance. Once started, it is a point of vantage for the attacks of agents of erosion, which thereupon are able to increase their work at an accelerating rate of speed. Only next in importance is the definition and fixing of embryonic depressions and gullies. Both these processes are carried out vigorously by these earth-flows, besides other processes such as the enlargement of valleys and channels already formed, the transportation of material, the destruction of the regularity of contours, and the transformation of surface rock material into a form easily removable otherwise, thus in every case supplying better leverage for further destructive action.

Earth-flows usually originate in minor depressions or in already well-formed gullies or valleys, these being the places most subject to the concentration of water: but in some instances they occur on the convex face of a slope, where the removal of soil develops a depression for the first time, and a new drainage line is made possible. The soft débris that is removed, although piled higher than the surrounding slope, lends itself easily to the formation of rivulets by the water that rises and collects in the excavation that is left. These small water-courses, once formed, control the line of flowage, and result in a sort of superimposed drainage when they have worn through the débris to the original slope below. Earth-flows of the above varieties, large and small, with the closely related types of earth-slumps, are thus among the important initial steps in the development of drainage lines in the California hills.

EARTH-LURCHES.

Of the three kinds of landslides thus far referred to, the first two, earth-avalanches and earth-slumps, occur quite commonly independent of earthquakes. Of the third kind, or earth-flows, the only examples that have been presented are immediately connected in genesis with the earthquake of April 18, although it is conceded that sudden accessions of water to loose earth might arise in other ways and occasion earth-flows. As regards the fourth type, the earth-lurch, it is difficult to conceive for it any other origin than an earthquake, since it is caused directly by the horizontal jerk of the ground and can not be produced in any other way. In the detailed account of the distribution of apparent intensity, a brief account of these superficial movements of the ground has been given and need not here be repeated. They are best exemplified on the flood plain of the Eel River, west and north of Ferndale; the flood plain of the Russian River; the flood plain of Alameda Creek, near Alvarado; the flood plain of Coyote River near Milpitas; the flood plain of Pajaro River; and the flood plain of the Salinas River. (Plates 136A, B and 137A, B.) In all these localities cracks were formed in the alluvium, generally parallel to the stream trench, and the ground between the cracks was caused to lurch horizontally toward the stream, usually with a rotation of the moved mass, which gave to it the profile of a Basin Range fault-block in miniature, the portion of the moved strip farther from the stream collapsing into the vacuity caused by the lurching.

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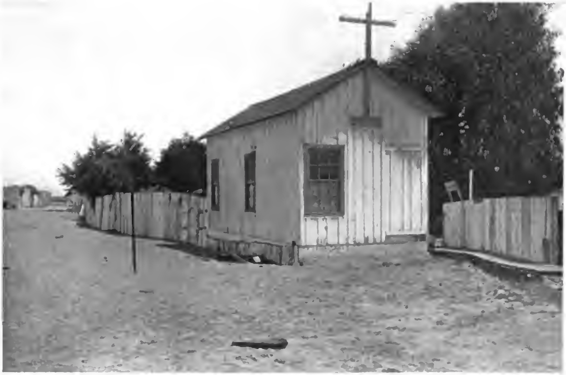
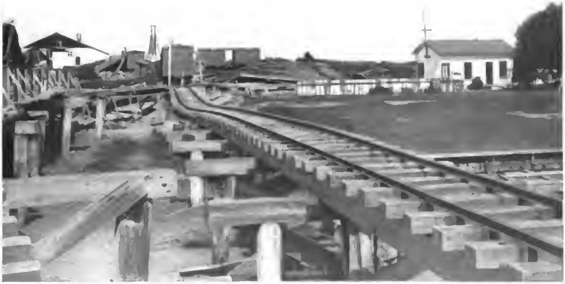
[1] G. A. J. Cole, Nature, Jan. 14, 1897, vol. 55, pp. 254–256. G. H. Kinahan, Nature, Jan. 21, 1897, vol. 55, pp. 268–269.

[2] W. M. Conway, Climbing in the Himalayas. New York, 1894, pp. 118, 129–130, 323–324.

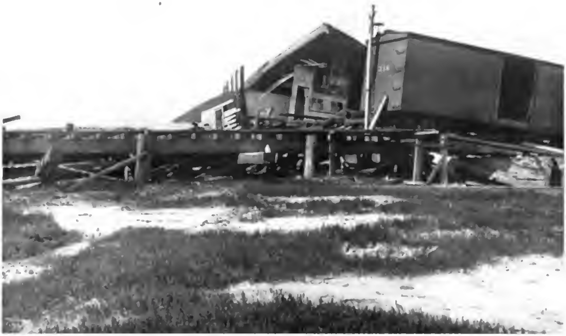
[3] T. G. Bonney, Moraines and Mud Streams in the Alps. Geol. Mag., January, 1902, p. 8.



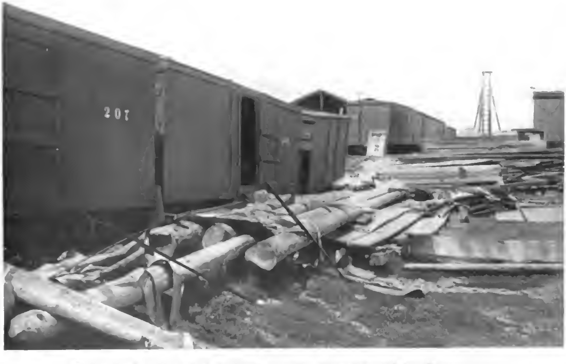
A. Moss Landing. House, tree, and fence moved 12 feet by lurching of ground toward Salinas River. A. C. L.



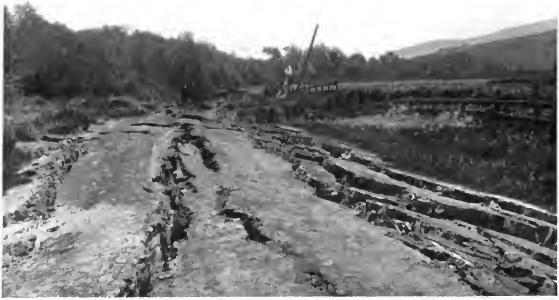
B. Moss Landing. Lurching of ground toward Salinas River carried piles from beneath bridge timbers, causing it to collapse. A. C. L.



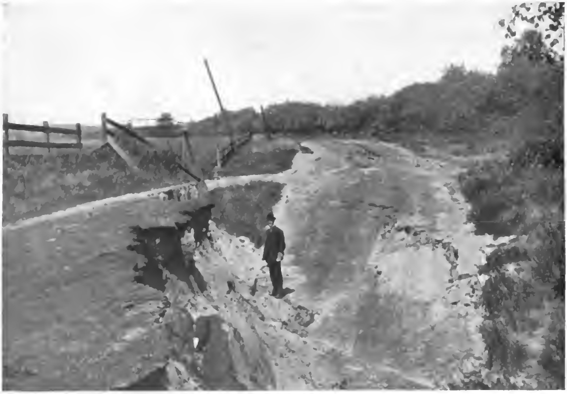
A. Moss Landing. Lurching of ground toward Salinas River, to left, carried piles from beneath bridge timbers and caused bridge to collapse. Displacement 9 feet. A. C. L.



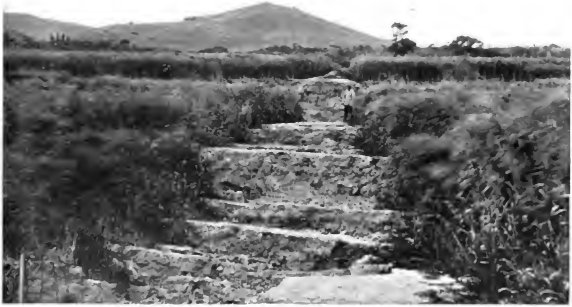
B. Moss Landing. Deformation of surface due to lurching of ground toward Salinas River. A. C. L.



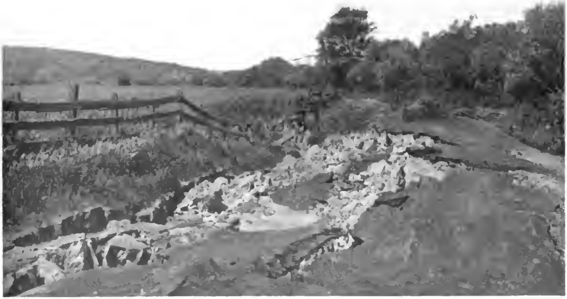
A. Lurching of ground toward Salinas River and consequent collapse. Near Spreckels. A. C. L.



B. A detail of view shown in A. A. C. L.



A. Lurching of ground toward Salinas River, with consequent collapse. Near Spreckels. Per J. C. B.



B. Destruction of road due to lurching of ground toward Salinas River. Near Spreckels. A. C. L.

Along the beach or sand-spit which separates the Salinas River from the Bay of Monterey at Moss Landing, there was a marked lurching of the spit toward the trench of the river as illustrated in plates 134A, B and 135A, B.

Lurching of soft ground was also exemplified on the tidal mud flats of Tomales Bay, and on the "made land" of San Francisco; but there being no trench in these cases, the movement caused a ridging of the surface with compensating depressions. In the case of the made land in San Francisco, and perhaps generally, the deformation of the surface due to lurching was complicated by the settling together of the loose material.

CRACKS AND FISSURES.

The cracks in the ground which appeared at the time of the earthquake fall into different categories. Of these there are two distinct classes:

1. The crack or fissure of the main fault, which is a superficial expression of the deep rupture of the earth's crust that caused the earthquake. Associated with this as a subclass are the auxiliary cracks and fissures which are superficial expressions of branch ruptures or subparallel ruptures, generally close to the main rupture in the Rift zone. In this class would also belong any cracks due to supplementary faulting in the general zone of disturbance, if such supplementary faulting exists, which is doubtful except in special instances.

2. The second general class includes those cracks and fissures which were caused by the earthquake, as a result of the commotion of the ground, and have, therefore, been designated as secondary.

The main crack, or fault-trace, and the auxiliary cracks satellitic to it, have been described in the section of the report dealing with the earth movement along the fault.

The secondary cracks, inasmuch as they are an indication of the intensity of the shock at any locality, have been described or referred to in the section dealing with the distribution of intensity. A brief review of the phenomena of cracks in the ground, apart from the main fault-trace and the auxiliary cracks in the Rift zone, will, however, be given, even at the risk of some slight repetition.

Since some of the cracks to be referred to can not with certainty be placed in one or the other of the two fundamental classes above indicated, it will be found convenient not to force that classification in all cases. Along the zone of the Rift there were many secondary cracks, as well as those classed as auxiliary; but it was not in every case possible to discriminate between them. These secondary cracks occurred both on hill slopes and in alluvial bottoms. On the hill slopes they were very commonly associated with landslides, or marked the inception of landslides; and these have already been discust. On the bottom lands of streams or embayments in the Rift zone, cracks in the ground were exceedingly common for the entire length of that portion of the Rift along which the fault extended. In very many cases these cracks were associated with the lurching of soft incoherent materials, just as the cracks on the hillsides were associated with more common phases of landsliding. There were also, however, many cracks quite dissociated from the deformation of the surface due to lurching, although there was doubtless in these cases an ineffective tendency to lurching.

Beyond the zone of the Rift, cracks were observed at many localities. These were most common on the bottom-lands of the streams, notably the Eel River (plate 138A, B), the Russian River (plate 139A, B), Coyote Creek (plate 140A, B), and other streams at the south end of the Bay of San Francisco, Pajaro River (plate 141B), San Lorenzo River, and the Salinas River. Many other smaller streams might also be mentioned. In these cases the cracks were usually associated with the phenomena of lurching of the alluvial deposits, though many cracks also occurred where no such association was apparent. They were in nearly all cases found to be parallel or sub-parallel to the nearest portion of the stream trench. They very commonly extended for several hundred feet, in some instances for several hundred yards, and were characteristically arranged in linear series. The cracks in the series in some cases overlapt *en échelon*, and in others they were in groups of parallel cracks in belts a few hundred feet wide. In no case was there any suggestion that they were more than purely superficial phenomena. A unique manifestation of surface cracks is that described by Matthes and Crandall in the vicinity of Livermore. (See plate 141A.)

On the hillsides and ridge crests, at points not within the Rift zone, cracks were of common occurrence. Most of these were connected with landslides, as has been indicated in the section dealing with that subject. Roadways and artificial embankments were particularly susceptible to damage from such cracks. But some of the cracks had no apparent connection with landslides, actual or incipient, and these are of especial interest. The most northerly are those described by Mr. E. S. Larsen in the region northwest of Covelo, Mendocino County, as set forth in the record of intensity. Some of the cracks described by Mr. Larsen crost the crests of rocky ridges; and altho it was not possible to follow them for great distances, they evidently extend down into the rock. It is remarkable that in the district where these cracks occur, there was no evidence of a local rise in intensity and, therefore, nothing to suggest that they were the seat of a supplementary local earthquake. The probable interpretation of the occurrence is that they are secondary cracks of a rather exceptional kind, in ground that required no very severe shaking to rupture it superficially. Cracks of a similar character were noted by Mr. C. E. Weaver in the Clear Lake district and on the flanks of Mount St. Helena.

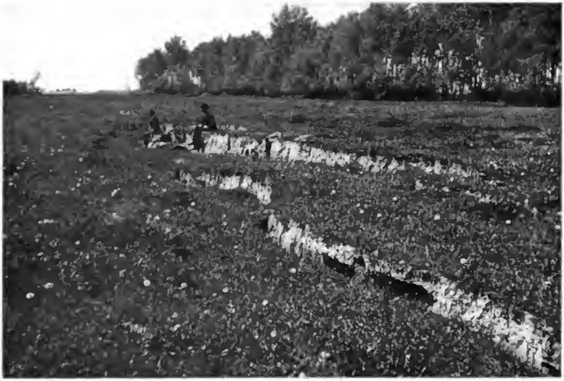
On the San Francisco Peninsula, similar cracks were observed by Mr. R. Crandall on Cahill Ridge and Sawyer's Ridge, and are described by him in his account of the distribution of intensity in that region. In the Santa Cruz Mountains, such cracks were common and are described more or less in detail in the section on the distribution of intensity. In general they appear to be the result of the earthquake rather than a contributory cause, although in some cases it is quite possible that they may have been local ruptures of the nature of auxiliary cracks and so gave rise to subordinate vibration.

EFFECT OF THE EARTHQUAKE UPON UNDERGROUND WATERS.

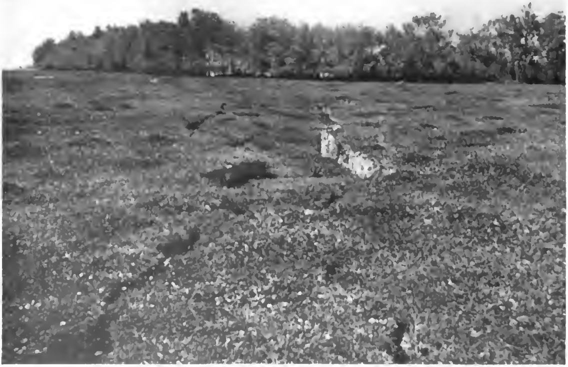
SIGNIFICANCE OF THE PHENOMENA.

Perhaps the most interesting and significant fact which the study of the earthquake has brought to light, apart from the great fault along the Rift, was the general disturbance of underground waters. In earthquakes generally, the phenomena which appear at the surface of the earth have become well known and, indeed, almost commonplace in recent years; but what transpires in the earth's crust below the surface, as the earth-waves generated at the seat of disturbance pass through it, is as yet a matter of uncertainty and inquiry. The effect of the shock upon the movement of underground water, as manifested by the behavior of springs and wells, throws light on this question. A few pages are, therefore, devoted to recording information of this kind.

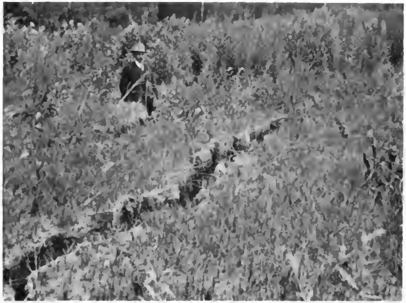
It appears from the reports that have come in that springs and wells were very generally and variably affected throughout the disturbed area, indicating a sudden derangement in the normal movements of such water. This derangement could only have been effected by the changes in spaces in the rocks in which the waters in the subsurface region are contained, whether flowing or stagnant. These spaces are of 4 general kinds: (1) interstitial spaces, or so-called voids, between the constituent fragments of imperfectly compacted rocks, such as sands, gravels, sandstones, conglomerates, tuffs,



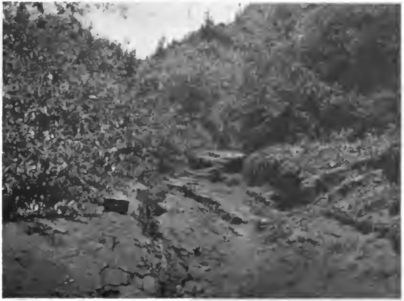
A. Eel River, near Ferndale. Cracks in flood-plain. A. S. E.



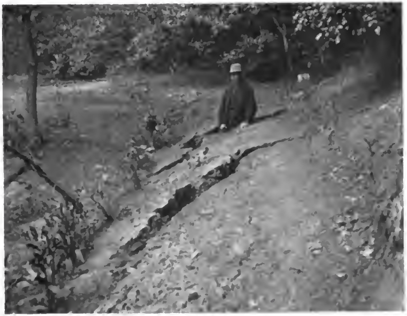
B. Eel River, near Ferndale. Cracks in flood-plain. A. S. E.



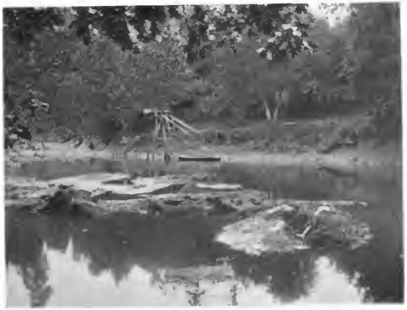
A. Russian River west of Windsor. Cracks in flood-plain. R. S. H.



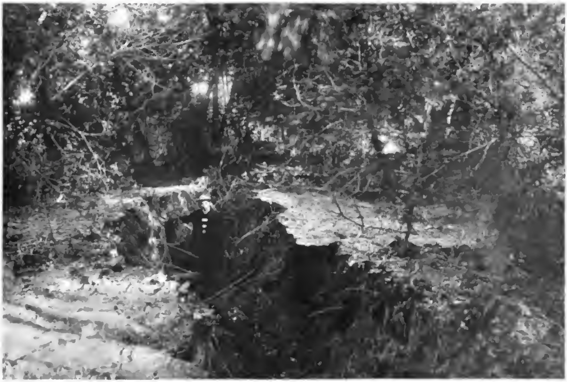
B. Russian River. Crack in flood-plain parallel to river. R. S. H.



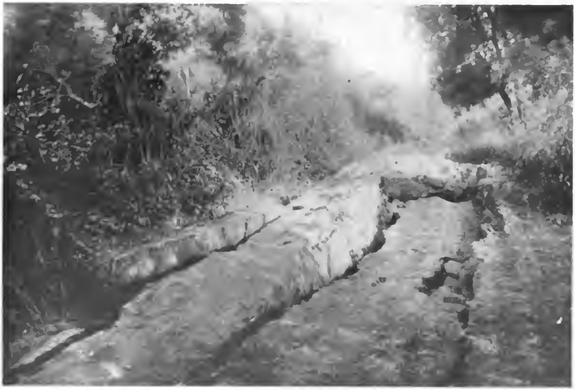
C. Fissures in alluvium; Tevis ranch, near Alma. I. H. S.



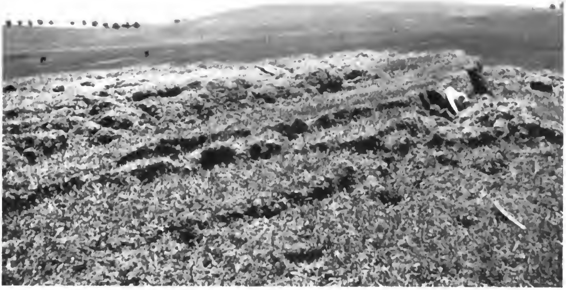
D. Upheaval of bottom of artificial lake; Tevis ranch, near Alma. I. H. S.



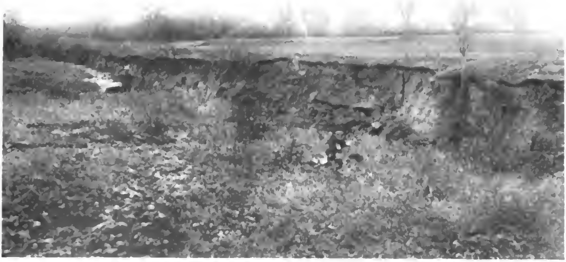
A. Secondary cracks in alluvium near Milpitas. Per J. C. B.



B. Secondary cracks in alluvium on banks of Coyote Creek. Per J. C. B.



A. Concentric cracks in ground around an old alkaline spring, 1.5 miles north of Livermore. E. C.



B. Secondary crack, with drop of 7 feet, in alluvial flood-plain of Pajaro River. G. A. W.

etc.; (2) the cracks and fissures which traverse the more firmly compacted forms of the same rocks, or others, such as granite, lava, etc., which occur only in a solid or coherent condition; (3) the vesicular spaces and tunnels of lavas, and (4) the spaces of dissolution which occur frequently in relatively soluble rocks, notably limestone. The occurrence of water which does not permeate the rocks nor flow thru them, but is contained in small discrete cavities in rocks, such as the liquid inclusions in igneous rocks and in the constituent minerals of sedimentary rocks, is here ignored. Thruout the Coast Ranges of California, limestones are not abundant and spaces of dissolution are believed to have played no part in the changes which were manifested in the behavior of springs and wells. The same remark holds with reference to vesicular and tunneled lavas. These changes were thus confined to the voids of porous and usually little coherent rocks and to cracks and fissures which traversed the coherent rocks, whether porous or not.

In the discussion of certain earth-flows in the preceding section of this report, the initiation of which is ascribed to a sudden accession of water from the underlying formations, attention has been already directed to an extreme phase of the disturbance of the normal conditions of the ground-water. In those cases the ground-water was suddenly expelled or squeezed out of saturated, incoherent formations at the time of the shock. They are extreme manifestations of a tendency which affected the ground water generally thruout the disturbed region. In this connection, it may be well to direct attention more particularly than has hitherto been done to the behavior of water contained in the alluvium of the river-bottoms. One of the most common phenomena in such situations was the expulsion of water in jets from apertures which suddenly appeared in the flat-lying ground. The water was usually thrown into the air for several feet; in some cases it was reported to be as much as 20 feet, and the ejection continued for several minutes after the earthquake. The continuance of the ejection after the shock indicates that an elastic stress had been generated in the saturated ground, which thus found relief in the expulsion of the contained water or that there was a gravitational settling together of the material, which diminished the spaces occupied by water. The vents thus established were very numerous, and were in many instances closely spaced; more frequently a few to the acre, and occasionally isolated. These vents were easily recognizable for weeks and even months after the earthquake, in the form of craterlets. The water in its passage to the surface brought up considerable quantities of fine sand, which, from its prevailingly light bluish-gray color, was evidently derived from considerable depth. On the flood plain of the Salinas River, the sand was recognized by the people of the neighborhood to be the same as that of a stratum of sand pierced by wells at a depth of 80 feet. The craters were usually distinctly funnel-shaped and were rimmed by a circular flat ridge of sand which, by reason of its light color, was in marked contrast to the surrounding surface. They varied in diameter from 1 to perhaps 10 feet. In some instances the funnels were several feet deep; in others the feeble action in the closing stages of the eruption had caused them to fill up with sand. They were quite analogous to the craterlets described and pictured in Dutton's account of the Charleston earthquake.[1] (See plates 142A, B and 143A, B.)

These craterlets occurred on practically all the saturated alluvial bottoms of the streams within the zone of destructive effects, and also on the tidal mud flats of Tomales Bay. They are significant of the compression to which such water-laden, incoherent formations were subjected by the passage of the earth-waves at the time of the earthquake or by the consequent settling of the ground. They thus afford us, in part at least, a key to the behavior of many springs and wells. Most of the springs of the Coast Ranges are in solid rock, though they may emerge on a hillside mantled with regolith and soil. Such springs, as a general rule, had their flow increased at the time of the earthquake. The tendency to compression in firm rocks would not be so effective as in the case of noncoherent sediments, but it would make itself manifest in the generation of an elastic stress which would die out and merge with the normal gravitative stress very gradually. There would also be an effective tendency to bring together the walls of cracks and fissures whose planes lay transverse to the path of propagation of the compressive wave. Both of these tendencies would make for an expulsion of the water. The expulsion could not, in most cases, be effected suddenly, however, owing to the great frictional resistance; and simply resulted in an increased flow of the springs at the surface, which would continue during the life of the abnormal elastic stress. The duration of this stress appears in some cases to have lasted but a few days; in other cases it continued for 2 months, as inferred from the abnormally large flow of the springs. This variation would depend on local conditions, such as the superficial or deep source of the water, the character of the rocks, the degree to which it was seamed with cracks, etc.

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[1] U. S. Geological Survey, 9th Ann. Report, pp. 296-298.

This same general explanation would apply to artesian wells, in which the water acquired and maintained an increased head for some time. In some such wells, where the water stood normally at some little distance below the surface, it overflowed and flooded the ground in some instances. In other cases, where the supply was not artesian, but shallow wells reached the ground-water, the level of the latter rose. This general tendency was complicated in some instances by other effects of the earthquake. Several surface wells had their level lowered, and others went dry. This sudden drop in the level of the ground-water can be explained only by a sudden draining off of the underground waters to lower levels, and this might be effected by the opening up of the ground superficially, in consequence of the shock. A similar explanation would apply to the few springs which had their flow diminished or cut off altogether. This draining off of the waters of higher levels would also augment the flow of springs and wells at lower levels and may in some cases have been the principal cause of observed increases of flow. The noteworthy case of the spring near Ukiah, described below, which ceased flowing and remained dry thruout the following summer and fall, but resumed its flow with the advent of the winter rains, suggests that the fissure in the rock from which the spring welled served as the limb of a siphon and that the water in the siphon was drained off in consequence of the agitation and opening of the ground at the time of the shock. The winter rains refilled the siphon limb and so brought about a resumption of the flow.

One of the most common reports regarding the shallower wells was the roiling of the water by the admixture of earthy matter, doubtless due to the agitation of the ground and the loosening up of the incoherent material at the bottom of the wells.

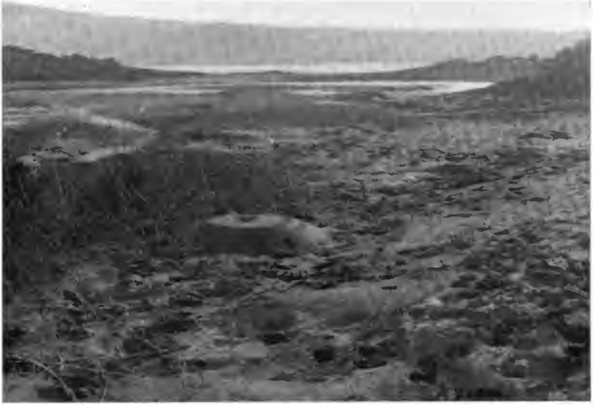
RECORD OF SPRINGS AND WELLS AFFECTED.

A brief and partial record of springs and wells affected by the earthquake follows:

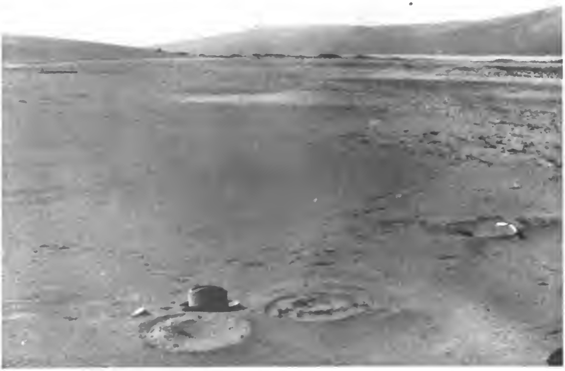
Montague, Siskiyou County (C. H. Chambers). — A sulfur spring was formed at a point 2 miles south of the town of Montague. Hot water ran from it for 2 days, after which it cooled off. A soda spring 9 miles east of the town doubled its flow. The water of many springs was muddy for several days after the quake.

Denny, Trinity County (P. L. Young). — At a small quartz mine near Denny the shock doubled the amount of water flowing from the tunnel.

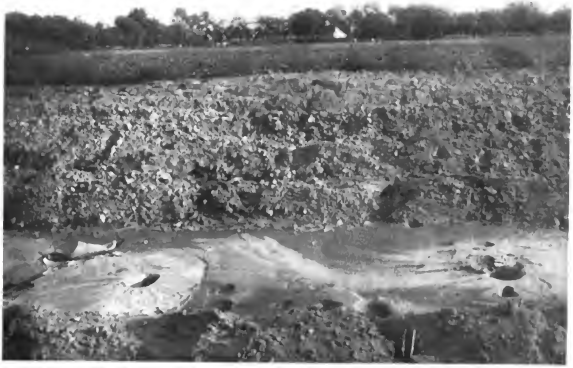
Peanut, Trinity County (Mrs. E. Diller). — There was an increase in the water in the ditch which comes from a small gulch. The increased flow had not diminished up to May 6, 1906.



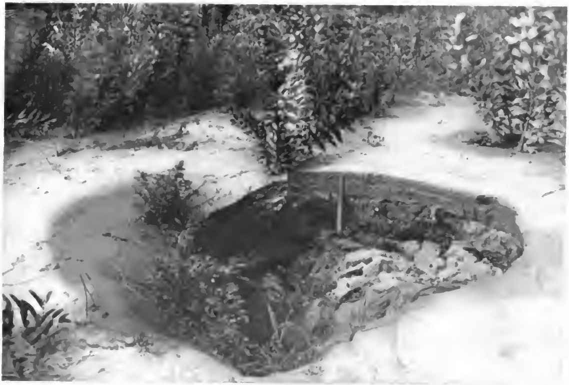
A. Craterlets in sand near marsh east of Bodega Bay. J. N. L.



B. Craterlets along fault-trace on sand spit at mouth of Tomales Bay. R. S. H.



A. Craterlets in fields near Milpitas. Per J. C. B.



B. Craterlets near Watsonville. Per J. C. B.

Briceland, Humboldt County (J. W. Bowden). — The pressure on the flow of natural gas was doubled in the vicinity.

Covelo, Mendocino County (E. S. Larsen). — Some springs and wells in the vicinity went dry, while others flowed more freely.

Laytonville, Mendocino County (A. S. Eakle). — A sulfur spring had its volume of water increased at least threefold by the shock, according to report.

Mendocino, Mendocino County (O. H. Ritter). — Wells in the lower part of town became full to overflowing and a heavy seepage of water was observed in the yard of the Alhambra Hotel.

(W. Mullen.)—The flow of a number of springs was increased.

Ukiah, Mendocino County (S. D. Townley). — The water in the well at the Observatory was very noticeably roiled for several days after the shock. The Ukiah press for April 27 reports some very marked changes in the flow of springs near Ukiah. A spring near the E. Clemens Horst Company's ranch, which supplied water for domestic and ranch purposes, stopt flowing after the earthquake. The ranch is about 2 miles north of Ukiah and a little west of the center of the valley, and the spring is in the foot-hills on the edge of the valley, nearly a mile to the west of the ranch. Pipes connected the spring with 2 tanks on the ranch, the spring having supplied the ranch with water for a great many years. The foreman, John Eldred, states that the day after the earthquake it was noticed that no water was flowing into the tanks from the spring. Investigation showed that the spring, which comes out of rock, was absolutely dry. Mr. Eldred and his men worked for two or three weeks, digging, drilling, and blasting, in the effort to regain a supply of water; but these efforts were futile and were finally abandoned. A well 75 feet deep was dug on the ranch and a wind-mill erected. Eldred went to the site of the spring several times during the summer and early fall, but there was no water. Upon going to the place in the early part of the winter, after the rains had begun, it was found that the spring was again flowing with a largely increased volume of water. He estimated that the flow was about doubled. The spring was still flowing with the increased volume on March 15, 1907.

Hemlock, Mendocino County (C. D. C. Bowen). — Some springs flowed more abundantly after the shock.

Lake County (C. E. Weaver). — At Highland Spring, in Lake County, none of the springs dried up, but one new soda spring was formed in the Franciscan rocks. The mineral springs in all parts of the county are reported to have increased in flow and number. The artesian wells in Scott's Valley, west of Lakeport, have diminished in flow, and several have stopt flowing. Many wells have dried up, but this was not confined to any particular locality or part of the county. The shock apparently had no effect upon the waters of the northern part of Clear Lake, nor upon the springs in that part of the district.

Lakeport, Lake County (J. Overholser). — The flow of many springs increased on account of the earthquake, while the flow of artesian wells decreased.

Annapolis, Sonoma County (G. W. Fiscus). — Wells and springs have gone dry in places, and water has come to the surface where there was none before.

Sebastopol, Sonoma County (R. M. Hathaway). — The wells in this vicinity were all stirred up, the water becoming filled with sediment, as tho a heavy rain had washt in surface water. A small brook a little to the left of a fissure in the soil on the Blundon place had its flow of water so increased that the owner of the place had his attention called to it by the roaring of the water.

Santa Rosa to Sonoma, Sonoma County (E. S. Larsen). — At the city pumping station, 1.5 miles east of Santa Rosa, there are 4 wells, dug 50 feet and connected with a tunnel 450 feet long. Within each well there is a bored well 8 inches in diameter and 108 feet deeper than the dug well. The water began to rise immediately after the shock, and is 15 feet higher than before, altho the pumps have been run to their full capacity.

The warm spring at Peters' ranch was little affected, except that for a day or so after the shock the water in the spring was lower. At Conrad ranch, northwest of Melita, there are numerous warm springs, about 100°, all along the base of a hill, which have had their flow increased very much. Mr. Striddle thinks that there is ten times as much water as before, and that it is a little warmer. He also tells me that the flow is gradually decreasing again. The springs at Melita, along the north side of the hill, have behaved much like those at Conrad's. I am told the creek about 2 miles to the north has risen considerably since the shock.

A mile north of Kenwood there is a well which was dried up about a year ago by an earthquake, and had to be dug deeper. This shock did not seem to affect it.

Glen Ellen Springs continue to be changed, usually increasing their flow, tho a few springs went dry. At McEwan's Ranch, 3 miles west, both cold and hot springs are flowing much more water. At the State Home at Eldridge, a warm spring started about 0.75 mile east of the town. Hot springs at Agua Caliente have nearly trebled their flow, and the temperature has risen from 112° to 114°. A spring which required pumping before now flows.

Boyes Hot Spring has increased a little and now flows without pumping. The temperature has also increased a little. Several years ago an earthquake stopt the flow, so that pumping has been required until this last shock. At Sonoma the wells and springs supplying the city are flowing more than before.

Veterans' Home, Napa County (A. Brown). — The earthquake caused the springs to flow more fully for about 2 months, after which they returned to normal.

Napa, Napa County (T. Hull). — In many cases springs increased their flow.

Redding, Shasta County (L. F. Bassett). — Some springs have been reported to have increased their flow and to have a lower temperature.

McCloud River, Shasta County (*Chico Enterprise*). — Springs in the limestone belt above Baird, which were formerly cold and clear, became warm and milky.

Allegheny, Sierra County (W. A. Clayton). — The earthquake changed the flow of water in mines and springs.

Suisun, Solano County (E. Dinkelspiel). — Mr. Miller's gas well, 3 miles northwest of Suisun, gave threefold greater volume of gas for 2 weeks before the earthquake than it did afterward.

Martinez, Contra Costa County (R. Wulzen). — Alhambra Creek is said to have risen 2 feet after the earthquake. A small stream to the east of the town, which is usually dry by May 1, now has considerable water. The same is reported of another stream south of town. A well in the vicinity, in which the water has always been several feet below the surface, is reported to be filled almost to the surface.

Stockton, San Joaquin County (R. Crandall). — An old disused gas well at the City and County Jail had a flow of water started in it by the earthquake. This flow continued for about two weeks, after which time it began to diminish. In a gas well, at the City and County Hospital, both the gas and water flow had been doubled and had continued so up to the time of my visit.

Ripon, San Joaquin County (T. H. Wren). — I have 18 acres of alfalfa land, which watered with an inch less water over the head-gate in 1905, in 17 to 20 hours. This year it took 25 hours to water 13 acres, all conditions being the same as last year except that the land was more packed and should have watered quicker. Others have made the same observation.

Sunol, Alameda County (R. Crandall). — The level of the ground-water around Sunol was affected considerably. In most of the wells the water rose, some overflowing for a short time. The postmaster gave 4.5 feet as the measured rise of the water in his well. The spring which furnishes the town supply is said to have been diminished by one-fourth of its flow. Two other changes in water supply were reported: one being the starting of a new spring near one of the western Pacific camps in Niles Canyon; the other the rejuvenation of an old sulfur spring near Sunol, which had not flowed for many years.

Calaveras Valley, Santa Clara County (G. F. Zoffman). — The springs near Mr. Robert Ingleson's house, in section 22 on the ridge east of Calaveras Valley, became muddy after the shock and remained so for two or three days. The volume of water discharged by the springs increased to about four times the usual amount.

Alvarado (E. W. Burr). — At the Alvarado Sugar Mill, in several wells, formerly flowing artesian wells, the water-table is now a few feet below the surface, the water-level having risen at the time of the earthquake. In the accompanying table are given the heights of water in a number of wells about the mill, referred to an assumed level 30 feet above an assumed base. These wells were observed daily before and after the earthquake. In most of them the water suddenly rose. The readings show that in a few cases the water rose from 1 to 2 feet. A well which used to be considered nearly dry began showing daily fluctuations, overflowing nearly every morning for some weeks after the earthquake.

The figures here given are for measurements made on April 9 and 14, preceding the earthquake of April 18, 1906, and the measurements made on April 21 and 28 of the same month, and May 5 subsequent thereto.[1]

Heights of water referred to an assumed level 30 feet above assumed base.

No. of Well.	Approx. Depth (feet).	April 9.	April 14.	April 21.	April 28.	May 5.
1	470	22.89	24.81	26.14	26.31	26.56
2	312	26.64	26.81	28.14	25.48*	28.23
3	318	26.22	25.47	28.05	27.97	27.30
4	402	26.62	26.87	28.37	28.20	28.28
5	405	26.67	28.17	28.34	28.25	28.42
6	402	26.70	28.28	28.37	28.03	28.45
7	399	26.79	26.87	28.45	28.04	28.45
8	45	26.79	26.87	28.45	28.04	28.45
9	514	25.36	25.36	26.60	26.94	27.19

* No. 2, April 28. House pump was taking water from this well when measurement was taken.

San Francisco Peninsula (R. Anderson). — Thruout the central portion of the San Francisco Peninsula, the chief geological effects, aside from the actual displacement along the fault and the slumping and settling of alluvial ground, were the increased circulation of water and its discharge at the surface. The normal flow of water from springs was much disturbed. The water was usually muddy or milky. It is reported to have flowed salty from one spring for 2 days after the earthquake; after this it returned to its usual purity. Streams were considerably swollen temporarily, and water frequently came to the surface where it had not made its appearance before.

(R. Crandall.) — At Mr. Ebright's place, at the lower end of the lake in Pilarcitos Canyon, the spring water used for house supply is said to have been milky white the day of the earthquake. At Byrne's store, on the Half Moon Bay road, 0.5 mile west of Crystal Springs Lake, it was reported by the keeper that the water from their spring on the day of the shock was muddy and was not tasted; on the second day it had a very salty taste, and on the third day was again normal.

Santa Clara Valley (J. C. Branner). — At Menlo Park, a mile nearer Fairoaks Station, an artesian well flowed faster after the shock. At the Seale place, on the Embarcadero road, from the railway crossing at Palo Alto toward the Bay of San Francisco, a well was reopened. Other wells showed an increased flow and brought up sand. At Guth Landing, and southward along the road into Mountain View, the flow from bored wells had increased. A wind-mill which had for years pumped water from a well was no longer necessary, but the artesian water was muddy. At the Ynigo Ranch, 3 miles northeast of Mountain View Station, there was an artesian well which had, before the shock, flowed slightly or not at all, and a wind-mill was used to raise the water. After the shock it was found that the casing had been shoved up 2 feet, damaging the pump. The flow of water was increased, and black sand was brought up. Another well at this ranch was unaffected. Along the Jagel Landing road, 2 artesian wells had increased pressure after the shock. An old artesian well filled with stones had begun to flow for the first time in several years.

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[1] Since the wells in this district fluctuate in level with the rise and fall of the tide in the bay, a correction would have to be made for this influence before the effect of the earthquake upon the underground water could be inferred from the figures given in the table. If the hour at which the level of the water in the wells was measured is known, the correction may be ascertained and applied at any time.
A. C. L.

(H. H. Taylor.)—The water in an artesian well 215 feet in depth, near Millbrae, was roiled by the earthquake and remained so for several days.

San Jose, Santa Clara County (G. F. Zoffman). — Water and mud are reported to have spurted from many artesian wells.

(W. S. Prosser.)—A well near San Jose was reported as having increased in flow the day before the earthquake.

Gilroy, Santa Clara County (M. Connell). — It is reported on good authority that at Gilroy Hot Springs the temperature of the water rose nearly 10° and the flow increased to 5 times the usual volume.

Bellvale, San Mateo County (Miss L. E. Bell). — Some springs dried up and others broke out with a great gush of water, where no water had flowed before. An oil well from which tepid salt water, oil, and gas had been flowing since 1898 became suddenly dry and a similar flow began in another well 2,000 feet deep, at a distance of 600 feet to the east of the first well, where before nothing had been found.

Wright, Santa Cruz County (Miss F. Beecher). — Most of the springs are running with a greater flow since the earthquake; but the water in our well on top of the ridge sank rapidly to the level it usually holds in August. The water in all wells was very roily for some days.

Summit Hotel, near Wright, Santa Cruz County (H. R. Johnson). — The well at the summit, from which the Summit Hotel obtains its water, has its bottom on solid rock. After the shock the level of the water in the well rose 12 feet.

Boulder, Santa Cruz County (J. C. Branner). — At a sawmill near Boulder Creek, water stopt running from a hitherto permanent spring, but another in the neighborhood was flowing more freely than before.

Felton, Santa Cruz County (Miss F. Locke). — All the springs on the property of Miss S. Anderson, a mile east of Felton, greatly increased in flow.

Soquel, Santa Cruz County (W. E. Wheaton). — I have a drilled or bored well, yielding a magnificent flow of clear water. From three to four weeks previous to the earthquake this 75-foot well began to show signs of agitation below the surface. Every few days water heavily mixed with sand and ground chalk rock was pumped up. I knew that something was going wrong down under the earth, owing to the action of this well. When the quake came, it drove both fine and coarse sand into the casing, which put the well out of commission entirely.

Chittenden, Santa Cruz County (G. A. Waring). — Near Chittenden a marked increase was noted in the flow of oil and water, and more gas and sulfur appeared. In the neighborhood of Santa Ana Peak, the flow of springs was increased.

Prunedale, Monterey County (H. H. McIntyre). — Water started in many places where there had been little or none before the earthquake.

Salinas, Monterey County (G. A. Daugherty). — In many places water came up thru open fissures; in one place about 8 miles from Salinas, the water covered about 80 acres of land.

(B. M. Abbott.) — Water spouted from holes in the ground to a considerable height, and flooded the fields.

San Ardo, Monterey County (G. A. Waring). — At San Ardo, quicksand was thrown up in a well, seeming to lessen the flow considerably.

Paraiso, Monterey County (A. S. Eakle). — At Paraiso Springs, the quake affected the underground waters. According to the owner, Mrs. Romie, the supply of water from the springs had been diminishing for some time, and the temperature had been decreasing. Immediately after the shock it became necessary to put in a large pipe to carry off the water, and the temperature has resumed its normal state.

Lonoak, Monterey County (J. Rist). — The earthquake caused springs to flow more; and the water rose in some wells.

San Benito Valley to San Joaquin Valley (G. F. Zoffman). — In some places about 5 miles northwest of Bell's Station, on the Pacheco Pass road, springs were reported to be flowing 2 or 3 times as much water as they had previous to April 18. At a ranch-house 7 miles from the pass, on the east side of Pacheco Pass, the increase in the flow of water from springs in the neighborhood was said to have been noticeable. Springs were reported to have opened up considerably thruout the region around Emmet P. O.

Stone Canyon, Monterey County (G. F. Zoffman). — In the neighborhood of Stone Canyon Coal Mine, the people claimed that there was a sudden rise of the water of the wells immediately after the earthquake.

Dudley, King's County (O. D. Barton). — The gas spring on sec. 22, township 25 S., Range 18 E. was started into great activity by the earthquake. Formerly there were 7 places where gas could be seen occasionally blowing off through a shallow pool of water. Now there are more than 50 places where gas blows off continuously. The quantity of water was greatly increased. Beneath these gas springs the ground is dry and hot.

Bakersfield, Kern County (A. G. Grant). — Artesian wells 30 miles north of Bakersfield were rendered muddy by the earthquake.

Gold, Madera County (T. J. Rhodes). — Several springs increased about one-third to one-half in volume.

Steamboat Springs, Nevada (J. A. Reid). — At these springs the water is constantly boiling. For about 3 days after the earthquake, the volume was considerably increased, and the water became noticeably turbid with mud. On the north end of the highest sinter terrace, where heretofore the waters had been invariably clear, considerable quantities of mud were discharged. This material is now lying dry on the white surface of the sinter and is gradually being blown away. At the extreme north end of the active springs, where several mud springs have always existed, the change was noticed in the increased activity. One in particular formed a low cone of dark-colored mud, which is now dried and cracked.

RECORD OF AFTER-SHOCKS.

The list of after-shocks given below has been compiled by A. O. Leuschner from all reports that have come to hand. These reports include not only communications in answer to the three circulars sent out, but also other reports by interested observers. In addition many shocks in the list were taken from the separate reports printed in this volume. For the sake of completeness the shocks reported by Prof. Alex. McAdie in his monthly reports of the California Section of the Climatological Service of the Weather Bureau have also been included. A number of shocks have been inserted in the first proof from Prof. Alex. McAdie's Catalogue of Earthquakes on the Pacific Coast 1897–1906.[1] It should be stated, however, that this list by no means represents a complete enumeration of all after-shocks felt in California since April 18. In general, it may be said that the list becomes increasingly incomplete with the lapse of time since the great earthquake. This is particularly due to the efforts made by some of the newspapers to suppress all news regarding earthquakes in California. The list may be considered complete only for Berkeley, California, where several observers have endeavored to record every shock. As a rule the observer's name is included in the last column, initials being used for observers who have reported more than one shock. A key to the initials is given at the end of the list. The times are expressed in Pacific Standard Time.

Record of after-shocks.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 18, a.m.	5 18 57	6	IV	Berkeley	S. A.
	5 19	2	III	San Francisco	A. G. McA.; J. G. P.
	5 19 10			do.	Feeble, A. G. McA.
	5 21	2	III	do.	Feeble, A. G. McA.; J. G. P.
	5 21 51	3	III	Berkeley	A. G. McA.
	5 22		III	Eureka	Northwest-southeast followed by a side cross-motion. Persons in beds resting east-west not awakened, A. H. B.
	5 25 54	4	III	Berkeley	S. A.
	5 26			San Francisco	Feeble, A. G. McA.
	5 27	2	III	do.	J. G. P.
	5 28 16	2	II	Berkeley	S. A.
	5 28 19	1	II	do.	
	5 30			Humboldt Lt. Stn.	
	5 34 10	2	II	Berkeley	S. A.
	5 35 01	1	II	do.	S. A.
	5 37 39		II	do	S. A.
	5 39 32		II	do.	S. A.
	5 43	3	IV	San Francisco	Feeble, A. G. McA.; J. G. P.
	5 43 50	3	III	Berkeley	Two separate jerks, S. A.
	5 48			Phœnix (Ariz.)	Slight. West to east.
	5 59 13		II	do.	S. A.
	6 00			San Mateo Point	
	6 06			San Francisco	Light, N. E.
	6 10 36	7	III	Berkeley	2 max., one at 36 s., one at 41 s., S. A.
	6 28 13	2	II	do.	S. A.

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[1] Smithsonian Miscellaneous Collections, part of vol. XLIX.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 18, a. m.	6 30			San Francisco	Light, N. E.
	6 30 +		I–II	Mt. Hamilton	R. G. A.
	6 42			San Francisco	Light, N. E.
	6 44 11	6	II –	Berkeley	S. A.
	6 45			Mt. Hamilton	R. G. A.
	6 46 34		II	Mt. Hamilton	K. B.
	6 50		IV	Scott's Valley	F. L.
	6 52		IV	do	F. L.
	6 56				San Francisco Light, N. E.
	7 00			Cloverdale	Slight shock about 7 a. m.
	7 07		IV	Scott's Valley	F. L.
	7 20			Sausalito	
	7 30		IV	Scott's Valley	F. L.
	8			Sacramento	Slight shock soon after 8 a. m.
	8 02	2		Bonita Pt. Lt. St.	Nearly vertical; toward NW.; no tremor, just a jar; 1 max. strongest at beginning; no clock stopt, no sound.
	8 07			Yerba Buena	Light.
	8 10			Mile Rocks	Smart
	8 12	1–2		Mare Island	Slight shock.
	8 13			Antioch	
	8 14 14	10	IV–V	Berkeley	Was looking at watch when shock began. S. A.
	8 14 27		IV–V	do	At Students' Observatory, A. O. L.
	8 14 28 to 8 14 33			San Francisco	Sharp twisting motion, A. G. McA.
	8 14 39		II	Mt. Hamilton	A. M. H.
	8 14 45	3		Sacramento	
	8 15			Alcatraz	
	8 15	5		Oakland	
	8 15			Yountville	Severe.
	8 15	1	V	Mile Rocks	Strongest at middle, sound like cannon shot, following beginning 1 s. Sharp.
	8 15	2	V	San Francisco	
	8 18	4	III	do	
	8 19			do	N. E.
	8 19 20	5	V	Oakland	Northeast to southwest; 15 additional shocks by 1 p. m., duration 2–5 s., east to west, III–IV. 3 shocks between 1 and 3 p.m. 5 shocks between Apr. 18, 3 p. m., and Apr. 19, 6 a. m.
	8 20		IV	Scott's Valley	F. L.
	8 25		IV	do	F. L.
	8 30		II	Tuolumne	About $8^h 30^m$ a.m.
	8 30			Stockton	Very light.
	8 42			San Francisco	N. E.
	8 55		IV	Scott's Valley	F. L.
	8 58		IV	do	F. L.
	9 14			San Francisco	Sharp and short, A. G. McA.
	9 16 52		III	Mt. Hamilton	K. B.; A. M. H.
	9 17		IV	Scott's Valley	F. L.
	9 19		IV	do	F. L.
	9 20	1–2		Mare Island	
	9 22		IV	Scott's Valley	
	9 26			San Francisco	Moderate, A. G. McA.
	9 26 10	2	II	Berkeley	S. A.
	9 28	2	III	San Francisco	
	9 30	20		Southampton Shoal	N.-S. Horizontal tremor 10 s. before, 1 sharp shock, rumb.
	9 30			Mt. Hamilton	One other between $6^h 45^m$ and $8^h 15^m$, R. G. A.
	9 32	1		Scott's Valley	F. L.
	9 38	180		do	F. L.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h m s	secs.			
Apr. 18, a. m.	9 40	1		Scott's Valley	F. L.
	9 48			do	F. L.
	9 48			San Francisco	N. E.
	9 51 55			Berkeley	Ewing seismograph by R. T. C. and S. E.
	9 54 30	1	III	San Francisco	
	10			Lakeport	Slight (about 10. -).
	10			Oakland	
	10			Upper Lake	Not very perceptible, but stopt some clocks.
	10 04 39	10	IV	Ukiah	Increasing intensity with principal disturbance near middle of series. No clock stopt, S. D. T.
	10 05		IV	Cloverdale	Oscillatory motion east-west.
	10 05			San Francisco	N. E.
	10 05 47			Point Reyes	Two distinct vibrations from north to south.
	10 05 50			Farallones	Felt by Mr. Legler at Pt. Reyes, with whom I was talking over telephone at the time, about 3 s. before felt in Farallones. J. A. Boyle.
	10 06 29			Berkeley	Ewing seismograph by R. T. C. and S. E.
	10 07	1	II	San Francisco	
	10 22			Scott's Valley	Slight tremor, followed in about 30 s. by hard shake of several seconds. Fully the fifth hard shake since 5^h 13^m, F. L.
	10 30	15		Southampton Shoal	West-east. Apparent direction east. Tremor 5 s. after first shock, no noise.
	10 36	1	II	San Francisco	
	10 50			do	Moderate, A. G. McA.
	10 50 30	1	II	do	
	11			Scott's Valley	F. L.
	11 00		V	S. F. Peninsula	Distinctly felt on ground and caused falling of loose parts of buildings.
	11 06			San Francisco	Moderate, A. G. McA.
	11 06 23			Berkeley	Ewing seismograph by R. T. C. and S. E.
	11 06 27 + 2			do	Students' Observatory, A. O. L.
	11 07			Antioch	
	11 08	4	III	San Francisco	
	11 12			Scott's Valley	Longer than usual, F. L.
	11 15	2		Bonita Point	Nearly vertical.
	11 22	60		Scott's Valley	F. L.
	11 36 00	30	III	Ukiah	Southwest-northeast. No clock stopt, S. D. T.
	11 39		III	Cloverdale	Oscillatory motion.
	11 40			Upper Lake	Caused some clocks to stop; not all.
	11 47			San Francisco	Moderate, N. E.
	11 53 34		II	Mt. Hamilton	A. M. H.
	11 53 37		III	do	Vertical, K. B.
Apr. 18, p. m.	12 03			Oakland	Harbor Lt. St'n, Alameda Pier.
	12 03			San Francisco	
	12 03 43			Berkeley	Ewing seismograph by R. T. C. and S. E.
	12 03 44	2	II+	do	Faculty Club, S. A.
	12 03 52			do	B. L. N.
	12 04	4	III	San Francisco	A. G. McA.
	12 11			do	Very light, A. G. McA.
	12 13	3	II	do	A. G. McA.
	12 25			Eureka	Slight and of short duration, A. H. B.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 18, p. m.	12 31		III	Los Angeles	
	1 02			Scott's Valley	F. L.
	1 55	4	II	San Francisco	
	1 57			Scott's Valley	F. L.
	2			Wright's Station	Slight. Four miles south of Wright's Station.
	2	15	IV	S. F. Peninsula	A little before 2 p. m.
	2 15			Humboldt Lt. Stn.	
	2 20	5		Southampton Shoal	Vertical throw north-south tremor 20s. before; no noise.
	2 20			Stockton	Very light.
	2 20			Scott's Valley	F. L.
	2 22	1–2		Mare Island	Slight.
	2 23 10		II	Mt. Hamilton	
	2 24			San Francisco	Very light, A. G. McA.
	2 24 37			Berkeley	Ewing seismograph, R. T. C. and S. E.
	2 25	4	III	San Francisco	
	2 25			Salinas	
	2 25			Los Gatos	I. H. S.
	2 25			Oakland	Alameda Pier.
	2 27	1–2		Mare Island	Slight.
	2 28			San Francisco	Very light, A. G. McA.
	2 28 36		III	Mt. Hamilton	A. H. M.
	2 28 50			Berkeley	B. L. N.
	2 29			Sacramento	Very light.
	2 30			Antioch	
	2 30		IV	Scott's Valley	Extra hard, stopt clock hanging on wall facing south, 20″ pend. Stopt clock facing NW. by WNW., pend. about 5″, F. L.
	2 30			4 miles south of Wright's Station	Slight.
	2 30		VI	Ukiah	Stopt clocks (counted 35 shocks up to April 30), S.D.T.
	2 30	4	III	San Francisco	
	2 30			Salinas	
	2 32			Los Gatos	I. H. S.
	2 35	5	III	San Francisco	
	2 35		VI	Ukiah	
	2 35		III–IV	Scott's Valley	Extra hard, F. L.
	2 40			Salinas	
	2 43			Scott's Valley	Lighter, F. L.
	2 50			do.	Lighter, F. L.
	3		V	Los Gatos	Little if any vertical movement. A muffled sound, like distant blasting heard in a mine, was noticed just preceding minor shocks which followed, including that about 3 p. m., I. H. S.
	4 26	10	IX–X	Raleigh	Three shocks.
	4 28	15		Ballast Point	Vertical prop. SE. Increasing in intensity, strongest at middle. Clock stopt at 4^h 28^m 15^s pend. 18″, facing E.
	4 28			Temecula	
	4 29 45	20	IV–V	San Diego	Northwest and southeast. Strongest apparently at beginning. Clock not stopt, but disturbed, losing about 1 m.; pend. about 26″. No sound phenomena.
	4 30			San Diego	Heaviest in 15 years, northeast-southwest.
	4 30		II	Ramona	A few seconds.
	4 30		III	San Bernardino	Southeast.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 18, p. m.	4 30			San Juan Capistrano	Slight.
	4 30			Hemet, Riverside.	Shock increasing and dying away.
	4 30			Yuma (Ariz.)	9 or 10 distinct shocks, slight rolling from east to west.
	4 30		IX	Brawley	Northwest-southeast chimneys fell to west. Movable objects in bldgs., thrown west-east. Oscillation followed by tremors. Clock stopt at 4^h 30^m, facing south.
	4 30	Few		Ballast Point	North-south. Horizontal. Clock stopt 4^h 30^m, facing NW., pend. 17".
	4 50			Oakland	Alameda Pier.
	4 50 38	1		Berkeley	Two tremors within 1 s., B. L. N.
	4 51			San Francisco	Very light, A. G. McA.
	4 52			Yerba Buena	Light.
	6 02 42	2	II	Berkeley	S. A.
	6 03 04	1	II	do.	S. A.
	6 12			Yerba Buena	Light.
	6 45			Antioch	
	6 50			San Francisco	Very light, A. G. McA.
	6 50	5		Southampton Shoal	North-south. Horizon direction south, two light shocks, rumbling following shock 2s.
	6 50			Oakland	Alameda Pier.
	6 51 29	8	IV	Berkeley	Faculty Club, S. A.
	6 51 35–45.			do.	Slight tremors during interval, B. L. N.
	6 51 58		I–II	Mt. Hamilton	
	6 51 58		II	do.	Vertical, K. B.
	6 52			Sacramento	Very light.
	6 53			Yerba Buena	Light.
	Sunset			Angel Island	Strong, rumbling.
	7	1–2		Mare Island	Slight.
	7			Stockton	Very light. Number of light shocks reported for several days, but hardly perceptible.
	7			Scott's Valley	Lighter, F. L.
	7 01			San Francisco	Very light, A. G. McA.
	7 23			Yerba Buena	Light.
	7 25			Scott's Valley	Lighter, F. L.
	9 10			do.	Lighter, F. L.
	9 43			do.	Lighter, trembling of house kept up for 2 m. or more, F. L.
	10			Lakeport	Light, about 10 o'clock.
	10 38			Scott's Valley	Sharp shock, rather long. Trembling of house kept up for 2 m. or more, F. L.
	11 10			do.	Trembling of house kept up for 2 m. or more, F. L.
	11 22			do.	Light shock, F. L.
Apr. 19, a. m.	1 30			Paisley, Oregon	Tremor.
	3	20		Eureka	Slight, A. H. B.
	3 07 00			San Francisco	Light, A. G. McA.
	5 22			Eureka	Slight and of short duration.
	6 07	23		Eureka	Slight, A. H. B.
	6 25 10 +	3	III	Berkeley	Time is from memory, failed to record shock at time, S. A.
		2–5	II–III	Oakland	Seven shocks between 6 a. m. and 2^h 15^m p. m.
	10 30	27		Eureka	Slight, A. H. B.
Apr. 19, p. m.	12 31 00	20–30		Los Angeles	Increased intensity, 1 max., strongest at middle. No sound.
	12 31 41			do.	

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 19, p. m.	12 33			Los Angeles	Two shocks about 6 m. apart followed by slight tremors for about 1 h.
	12 25	15		San Pedro	Horizontal tremors 10 s. before, increased intensity, strongest at end. No sound.
	1 13			San Francisco	Sharp, main portion with twist, A. G. McA.
	2 05			Reno, Nevada	
	3 +			Salinas	Another shock later.
	3 25		III	Sacramento	Seemed to be north and south.
	8 15-8 30		IV-V	Hagen, Wadsworth, etc.	On east slope of Virginia Range, Sierra Nevadas; northwest-southeast. During next 1.5 h. 3 more, G. D. L.
	10 45		III	S. F. Peninsula	Slight.
	10 55			Laurel Glen	Tremor with 2 sharp after-shocks.
	11 06			Yerba Buena	Light.
				Mile Rocks	Slight shocks during day.
	11 10	30		Eureka	A. H. B.
Apr. 20, a. m.	12 30	2		Southampton Shoal	Vertical; direction upward. Tremor, 5 s. after; 2 sharp shocks, cracking sound coincident.
	12 30 53			Ukiah	Shock too light to be felt. It was detected by motion of bubbles of latitude levels. The oscillation was ½ or 1 division (N. and S.) d = 1.0″, S. D. T.
	3	3		Eureka	South-north, slight.
	4 45 00			San Francisco	Tremor, A. G. McA.
	4 50			Napa	
	5			Laurel Glen	Short and sharp.
	5 31			San Francisco	Moderate, A. G. McA.
	6 10	3		Mile Rocks	Moderate.
	7	3		do	Vertical. Strongest at middle.
	7 13			Laurel Glen	Short and sharp.
	7 15			San Francisco	Moderate, A. G. McA.
	11 30			Tuolumne	About 11^h 30^m a.m.
Apr. 20, p. m.	12 33		III	Santa Monica	North-south. Time not accurate.
	2 30			Laurel Glen	Light.
	5 26	10	IV	S. F. Peninsula	
	5 49	3	III	do	Followed after 4 s. by another brief motion.
	8 23	15	III	do	Series of gentle tremors.
	8 28			Scott's Valley	Light but decided, F. L.
	9 03			do	Barely felt, F. L.
	10 26			do	
				Mile Rocks	Slight shocks during day.
Apr. 21, a. m.	3			Napa	W. H. M.
	4 45			Scott's Valley	F. L.
	6 28			San Francisco	Strong, A. G. McA.
	9 08			Scott's Valley	F. L.
	1 35	7	IV	S. F. Peninsula	Shaking houses 7 s. and repeated after 5 s.
	3 15	5		Mare Island	T. J. J. See.
	8 27			Scott's Valley	F. L.
				Mile Rocks	Slight shocks during day.
Apr. 22, a. m.	2 or 2 30			Felton	
	4 45			Scott's Valley	Two shocks barely separated, last continuing fully 5 s., each a good shake, not severe but steady, oscillating, F. L.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 22, a. m.	5 00	1.5	.....	Mile Rocks	Slight.
	6 58	....	.....	Scott's Valley	Two shocks barely separated, last continuing fully 5s.; each a good shake, not severe but steady, oscillating, F. L.
	7	3	.....	Mile Rocks	Moderate.
	7 03 00	....	.....	San Francisco	Light, A. G. McA.
	7 10	....	.....	Scott's Valley	A mere jolt, F. L.
	11 30	....	.....	Saratoga	Described as underground explosion, about $11^h\ 30^m$ a. m.
Apr. 22, p. m.	3	....	.....	Napa	W. H. M.
	3	3	.....	Mile Rocks	Moderate.
	3 17	2	.....	Bonita Point	Nearly vertical. Direction NW.; no tremor, just a jar, 1 max., strongest at beginning. No sound, may have been blasting.
	3 18 20	60+	III	Berkeley	Tremulous motion for 5 m. after shock. Long duration of trem. motion also observed by Mr. Huber, who was in laboratory at time, weighing chemicals, S. A.
	3 18 22	2	III	Oakland	C. B.
	3 19	....	.....	Yerba Buena	Light.
	3 19 30	4	.....	San Francisco	Moderate rocking, about four waves, A. G. McA.
	8 35	....	.....	Salinas	
	9 08	2	.....	Mile Rocks	Slight.
	10 40	....	.....	Salinas	
	11 20	....	.....	Scott's Valley	Tremor, F. L.
Apr. 23, a. m.	12 05 00	3	.....	San Francisco	A. G. McA.
	12 48	8	.....	Trinidad Head	East-west tremor 5 s. before, short and heavy; clock stopt $12^h\ 48^m$ a. m., facing east; sound like thunder, preceded and continued during shock; same throughout, no change.
	12 55	6	.....	Cape Mendocino	Vertical. Southwest-northeast. Direction NE. increasing intensity. Clock stopt. Pend. 22", facing SW. No sound.
	1 10	....	.....	Grant's Pass, Ore.	
	1 10	14	V–VI	Eureka	South-north. Stopt clocks, A. H. B.
	1 11	10	.....	Ferndale	Severe shock, J. A. S.
	1 12	....		Scott's Valley	Light and short, but decided, F. L.
	1 15	....	II	Crescent City	West-east.
	1 16	....	.....	do.	South-north. Woke up everybody, no damage.
	1 17	....	.....	Cape Mendocino	
	3	....	.....	Scott's Valley	"Just enough to waken me," F. L.
	6 07	4	.....	Eureka	South-north. Slight.
	6 30	3	.....	Ferndale	Severe shock, J. A. S.
	8			Salinas	
	8 10 10	3	III	Oakland	From east, C. B.
	9 15	4	.....	Mile Rocks	Moderate.
Apr. 23, p. m.	12 45	....	.....	Scott's Valley	Barely perceptible, F. L.
	12 48	....	.....	do.	Very light, F. L.
	12 50	....	.....	do.	More decided, F. L.
	2 50	30	.....	do.	Decided trembling lasting perhaps 30 s., F. L.
	3 51	1	.....	San Francisco	Sharp, downward jolt, A. G. McA.
	5 30			Salinas	

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 23, p. m.	5 45	3–4		Scott's Valley	Sharp, lasting 3 to 4 s., F. L.
	10 00		III	S. F. Peninsula	About 10 p. m.
	10 25	2		Mile Rocks	Moderate, 2 max.
	10 34			San Francisco	Moderate, A. G. McA.
	10 36	2		Bonita Point	Nearly vertical Direction NW., no tremor, just a jar, 1 max. strongest at beginning. No sound, may have been blasting.
	10 38 42	6	IV	Berkeley	2 separate shocks, 2d stronger, S. A.?
	10 38 44			do	2 separate shocks, 2d stronger, F. Smith.
	10 38 57?		III	do	Short and sharp. Northeast southwest. Tremulous motion for 6 m. In bed awake, but watch correction uncertain, R. T. C.
	10 39	3		San Francisco	East-west.
	10 55		II	Oakland	C. B.
Apr. 24, a. m.	1 25			San Francisco	Short, A. G. McA.
	1 32			do	Tremors, A. G. McA.
	2			do	Doubtful, A. G. McA.
	5 46			Salinas	
	10 15	95 m.		Berkeley	Slight continuous trembling, S. A.
Apr. 24, p. m.	1 14			San Francisco	Light throw, A. G. McA.
	4 45	75 m.		Berkeley	Slight continuous trembling, S. A.
	8 10	2		Mile Rocks	Slight.
	10	60 m.		Berkeley	Slight continuous trembling, S. A.
	10 45			Oakland	
	11 30			Berkeley	Reported by several. Mr. Wood also reports shock followed by unsteadiness of ground for over 1 h., S. A.
	11 42			Oakland	
Apr. 25, a. m.	1 26	3		Berkeley	Light shock, lasted about 3 s. after awake, S. A.
	4 30			San Francisco	A. G. McA.
	6 30 22	3	III	Oakland	Northeast to southwest, C. B.
Apr. 25, p. m.	12		V	Mills College	Many small shocks.
	12 40		III	Cloverdale	
	3			Mile Rocks	Slight.
	3	1	V–VII	Cliffs about Wood's Gulch	
	3 12	2	V	Bonita Point	Direction NW., no tremor, just a jar, 1 max. strongest at beginning, no sound, may have been blasting.
	3 15	15	V	S. F. Peninsula	Strongly felt on ground, causing landsliding along coast cliffs, lasting 10 s. with a slight repetition after 10 s.
	3 15	3	III	Oakland	C. B.
	3 15			Napa	Sharp, W. H. M
	3 15	7	IV–V	Berkeley	Walking with Dr. King, not felt by either of us, S. A.
	3 17			Yountville	Undulatory twist, quite severe.
	3 17 10			San Francisco	Double waves recorded on seismograph, W. R. E. and A. G. McA.
	3 17 15			Oakland	Noticed by G. K. G. on clock marked U. S. Observatory.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 25, p. m.	3 17 40		II–III	Mt. Hamilton	
	3 18 20			Berkeley	2 tremors about 5 s. apart Time is of last one, B. L. N.
	3 20			Oakland	Alameda Pier.
	3 20			Antioch	
	3 22			Niles	Many shocks during month, W. B.
Apr. 26, a. m.	3 20			Salinas	
	10 20			Scott's Valley	F. L.
	10 23			San Jose	
	10 29			Oakland	Explosion? Chabot Observatory.
	10 33 35		II	Mt. Hamilton	Jolt only, no swing, R. H. T.
Apr. 26, p. m.	1 45			Mile Rocks	Slight.
	5	1		Saratoga	Like explosion under foot, similar to shock of Apr. 22 at $11^h 30^m$ a. m. Light.
	8			Salinas	Very heavy.
	8 50	4		do.	
	9 38			Mile Rocks	Slight.
	9 42	2		Salinas	Other shocks reported, but not recorded.
	9 50	4		do.	Very heavy.
	9 50	2		Mile Rocks	Slight.
Apr. 27, a. m.	2			Salinas	Very heavy.
	6 15	4	II	Oakland	Chabot Observatory.
	10 30			Ferndale	Sharp.
	10 30			Eureka	Sharp.
Apr. 27, p. m.	1 07			San Francisco	A. G. McA.
	1 09 34		II	Berkeley	R. T. C.
	1 10			Hollister	
	1 12			do.	And many others.
	10 08 10	3	III	Oakland	East to west, Chabot Observatory.
Apr. 28, a. m.	12 35			Napa	Sharp, W. H. M.
Apr. 28, p. m.	5 40			Scott's Valley	F. L.
Apr. 29, a. m.	4 55	2		Mile Rocks	Vertical. Strongest at middle, sound like cannon shot, coinciding with beginning of shock. Sharp, following strongest disturbance 2 s.
	5	2		do.	
	9			Paisley, Oregon	Milk spilt northwest-southeast. About 9 a. m.
	11 20			Scott's Valley	Hard, not long, F. L.
Apr. 29, p. m.	4 08			do.	Hard, shook house well and lasted several seconds, F. L.
	4 09			San Francisco	A. G. McA.
	4 09 20	1–2		Mt. Hamilton	W. W. C.
	1 00			Oakland	C. B.
Apr. 30, a. m.	1 45	2		Mile Rocks	Slight.
	1 48	2		do.	
	1 57 30			San Francisco	A. G. McA.
	1 59 40			do.	Single swing, A. G. McA.
	2 01 22		III	Berkeley	Northeast-southwest. Short and sharp, R. T. C.
	7 10			San Francisco	A. G. McA.
	7 20			Oakland	Shocks from this date to May 17 seem to be of circular motion. No decided direction shown by Duplex seismograph. Tremors, vertical motion predominating. Chabot Observatory, C. D.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Apr. 30, p. m.	1 05	2		Mile Rocks	Vertical. Strongest at end.
	10 50			Scott's Valley	Barely perceptible, F. L.
	10 58			Cape Mendocino	Southwest. Vertical. Direction south, very light.
	11 10			Eureka	Slight.
May 1, a. m.	6 05	2		Mile Rocks	Slight.
	9 21			Cloverdale	
May 1, p. m.	9 19	15		Healdsburg	Very smart shock, perceptible roaring, oscillatory.
	9 30			Guerneville	Articles thrown from north to south. Cracked much plaster.
	9 45	1-½		Mile Rocks	Slight.
	9 57 55			Berkeley	A. O. L.
	9 58			do	Faculty Club, G. K. G.
	9 58 24	12	III	do	East-west. Several max. Had watch out in 3 s., slight shaking 30 s. more, S. A.
				Napa	No time given. Three light shocks during day, W. H. M.
				Peachland	No time given.
May 2, a. m.	12 36			Napa	Sharp, W. H. M.
	4 05			Los Gatos	I. H. S.
	6 51 30			San Francisco	Very light, A. G. McA.
	6 56 20		II	Oakland	Chabot Observatory.
	8 50			San Francisco	Very light, A. G. McA.
May 2, p. m.	4 51 13		II	Mt. Hamilton	C. D. P.
	4 53			Santa Cruz	Lively shake.
	9 22			Calistoga	
	9 58			S. F. Peninsula	
	10 53			Scott's Valley	Two vibrations apparently from SE., F. L.
				Laurel	No time given.
May 3, a. m.	1-3			Glenwood	12 quakes, each preceded by sounds.
	5 56	5		Scott's Valley	Reported as 6 a.m. in Santa Cruz. Strong vibrations east-west. Sleepers generally awakened, F. L.
	6			Santa Cruz	
	6			Point Pinos	Short.
	6			Los Gatos	Vertical, I. H. S.
	6			San Francisco	Very light, A. G. McA.
	6 20			Oakland	Chabot Observatory.
	9 41 22			San Francisco	Very light, A. G. McA.
May 3, p. m.	4 17			Los Gatos	I. H. S.
May 4, a. m.	12 05			Scott's Valley	"Wakened me," F. L.
	5			Point Pinos	
	5 25	5	II	Mt. Hamilton	Two distinct principal shocks, 0.5 s. apart, 3 s. after beginning. North to south. No sound. No vertical motion, J. D. M.
	5 28			Los Gatos	I. H. S.
	5 32			San Francisco	Very light, A. G. McA.
	6	12		Scott's Valley	Two people at least were awakened. Three shocks almost continuous, not severe.
	8 30	5		do	Very slight trembling for perhaps 5 s., F. L.
	10 29 30			San Francisco	Sharp jar, A. G. McA.
	10 40			Los Gatos	I. H. S.
				Campbell	No time given.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
May 5, a. m.	10 15	3		Mile Rocks	Moderate.
	10 28			Oakland	Chabot Observatory.
	10 29 30			San Francisco	A. G McA.
	10 29 43			Berkeley	Northwest-southeast. Single displacement to northwest, with return to southeast, B. L. N.
	10 29 45 + 2		II	do.	J. N. LeC.
	10 30		IV	S. F. Peninsula	
	10 30			Napa	W. H. M.
	10 30			Oakland	Alameda Pier.
	10 30 05	1		Mt. Hamilton	W. W. C.
May 5, p.m.	11 45	1		Mile Rocks	Slight.
				Campbell	
May 6, a.m.				San Francisco	Several tremors during early morning.
	3 05			Los Gatos	Rotary motion north-south. Vertical, I. H. S.
	7 29			San Francisco	Light, A. G. McA.
	8 40	1		Mile Rocks	Slight.
	8 59 20			San Francisco	Strong. Last one double wave. Felt like a push. Then more waves, A. G. McA.
May 6, p.m.	8			Bartlett Springs	
	8 10	10	VII	Upper Lake	Very violent, almost due east, sudden.
	8 12 34	25	III-IV	Ukiah	Direction west-east, increasing intensity. No max. No noise. Watch compared immediately; times probably not in error more than 2 s., S. D. T.
	8 17			do.	
	8 32			do.	
	9 +	5	VII	Upper Lake	Very violent, many clocks stopt, I. H. S.
	9 +			Los Gatos	
	9 45	1		Mile Rocks	
	11 15	1		do.	
	11 25			Los Gatos	Rotary, I. H. S.
				Blocksburg	No time given.
May 7, a.m.				San Francisco	Several tremors during night.
	3			Point Pinos	About 3 a.m.
	3 20	1		Mile Rocks	
	3 45			do.	
	5 07			San Francisco	Very light, several light tremors during night and early morning, A. G. McA.
May 7, p.m.	4 10			Los Gatos	Rotary, I. H. S.
	4 17 10			San Francisco	Sharp jar, A. G. McA.
	4 30			Bartlett Springs	
May 8, a.m.	4 30			Los Gatos	I. H. S.
	10 16			Yerba Buena	Light.
May 8, p.m.	12 12			San Francisco	Light, A. G. McA.
	11 40			Campbell	
	11 40			Los Gatos	North-south, I. H. S.
	11 40			Point Pinos	Indefinite as to a. m. or p. m.
	11 42			San Francisco	Sharp jar, A. G. McA.
	11 42 02	10	II-III	Palo Alto	No max. No noise. Also felt by Prof. L. M. Hoskins, but no time taken. Watch compared with standard clock at Ukiah at 10 p. m., May 8, and at 11 a. m., May 9. S. D. Townley.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
May 8, p.m.	. .. .	....	.....	Salinas	No time given.
May 9, a.m.	5 20	....	.....	San Francisco	Light, A. G. McA.
	5 44 13	....	.....	Palo Alto	Just one jolt. Not felt by Prof. Hoskins; absolutely certain it was quake, S. D. T.
May 9, p.m.	2	....	.....	Saratoga	About 2 p. m. Like explosion under foot.
	7 25	....	.....	Eureka	South-north. Several seconds. Shook windows.
	9 30	3	.....	Ferndale	J. A. S.
	10 30	....	.....	Salinas	
	.. ..	....	.....	Los Gatos	Two light shocks, I. H. S.
May 10, a.m.	12 15	....	.....	San Francisco	Light, A. G. McA.
	6 47	....	.....	Blocksburg	
	6 55	3	.....	Ferndale	J. A. S.
	6 59	4	.....	Eureka	Slight sudden jolt. South to north.
	10 45	....	.....	Blocksburg	One light shock.
	.. ..	....	.....	Los Gatos	One light shock, I. H. S.
	.. ..	....	.....	Laurel	No time given.
	.. ..	....	.....	Montague	No time given.
May 11, p.m.	1 10	2	.....	Mile Rocks	Slight.
	1 27 46	....	.....	Oakland	Chabot Observatory.
	1 27 50	25	.....	Bolinas	
	1 30	....	.....	Napa	W. H. M.
	1 30	2	.....	Bonita Point	Nearly vertical. Prop. NW. No tremor, just a jar, 1 max., strongest at beginning. Rumbling coincident with shake. May have been blasting.
	1 30 49	3	.....	San Francisco	Heavy, A. G. McA.
	1 40	....	.....	Salinas	
	1 40 4±10	....	II +	Berkeley	Residence 1820 Walnut St.
	1 45	....	.....	Kentfield	
	.. ..	....	.....	Los Gatos	One light shock. No time given, I. H. S.
	3 30	....	.....	Napa	W. H. M.
May 12, a.m.	4 00	....	.....	do	North-south.
May 13, p.m.	7 50	....	.....	do	North-south.
May 14, p.m.	5 19	....	V	S. F. Peninsula	Caused ground to tremble distinctly, and brought down broken plaster.
	5 21	....	.....	San Francisco	Sharp jar, A. G. McA.
	9	....	.....	Campbell	
	9	....	.....	Los Gatos	North-south, I. H. S.
	9 03	....	.....	San Francisco	Light, A. G. McA.
May 15, a.m.	12 30	....	.....	Berkeley	G. K. G.
	1 10	....	.....	do	G. K. G.
	2 20	....	.....	Point Pinos	Vertical.
	9 20	....	.....	Mile Rocks	Moderate.
	11 53	....	.....	Los Gatos	I. H. S.
	11 56 47	5	II-III	Mt. Hamilton	Ending with jolt, Mrs. R. G. A.
May 15, p.m.	4 20	....	.....	Los Gatos	I. H. S.
	.. ..	....	.....	Campbell	No time given.
May 16, a.m.	5 20	3	.....	Ferndale	J. A. S.
May 16, p.m.	11	....	.....	Heber	
	11 30	....	.....	Berkeley	G. K. G.
	.. ..	....	.....	Salinas	No time given.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
May 17, a.m.	During night	....		Imperial	Two slight shocks.
	12 18	....	VI	S. F. Peninsula	One of the severest since the first shock, woke all sleepers, swayed houses, set dogs barking.
	12 30	....	.....	Berkeley	G. K. G.
	12 35	....	.....	Los Gatos	I. H. S.
	11 05 45	....	.....	San Francisco	Light, A. G. McA.
	3 40	....	.....	Ferndale	Two more before 6 a.m., J. A. S.
May 17, p.m.	8 15	35	.....	Mile Rocks	Vertical. Strongest in middle.
	8 17	....	.....	Oakland	Alameda Pier.
	8 17	....	V	Los Gatos	Short, but with considerable vertical motion, I. H. S.
	8 20	....	.....	Salinas	
	8 20	2	.....	Bonita Point	Nearly vertical. Direction N., no tremor, just a jar, 1 max., strongest at beginning. No sound, may have been blasting.
	8 20	22	.....	Point Pinos	Horizontal. Two max. alike, sound like water in pipe with air in it.
	8 20	....	.....	Oakland	Chabot Observatory.
	8 21	20	VI	S. F. Peninsula	About the heaviest since first shock, causing people to rush out-of-doors.
	8 21	....	.....	Napa	W. H. M.
	8 21	....	.....	Gonzales	
	8 21	....	.....	Campbell	Violent.
	8 21 17	12	IV–V	Oakland	Chandelier swung with period of 1.25 s. Shock NW.–SE. at Vernon St., R. T. C.
	8 21 22	14	IV	Mt. Hamilton	Vertical slightly, 2 max. 5 s. and 10 s. after beginning, mean of two observers, W. W. C.
	8 21 34	8	.....	Berkeley	East-west, A. O. L.
	8 21 40	8	III	Bolinas	S. A.
	8 22	....	.....	Yerba Buena	Light.
	8 22 25	....	.....	Berkeley	Faculty Club. G. K. G.
	8 24 30	....	.....	San Francisco	Moderate rolling motion, A. G. McA.
				do.	
	8 24 33	....	.....	Oakdale	Very slight. No time given.
	8 30	2	.....	Southampton Shoal	Southeast-northwest. Rumbling before shake and continuing 2 s. after.
	.. ..	....	.....	Livermore	No time given.
	.. ..	....	.....	San Luis Obispo	No time given.
May 18, a.m.	12 22	....	.....	Berkeley	G. K. G.
	1 45	....	.....	do.	G. K. G.
	5	....	.....	Los Gatos	I. H. S.
	5 23	....	.....	San Francisco	Light. A. G. McA.
May 18, p.m.	7 56	....	.....	Los Gatos	I. H. S.
	8 30	2	.....	Cape Mendocino	Southwest. Vertical. Direction S. Very light.
	8 53 37	3	II–III	Ukiah	No max. No sound. Watch compared immediately and clock correction determined within an hour, S. D. T.
	8 55	2	.....	Ferndale	J. A. S.
	8 55	....	.....	Fort Bragg	
	9 30	....	.....	Blocksburg	
	10 53	....	.....	Los Gatos	I. H. S.
May 19, a.m.	Between 12–2	....	.....	do.	Slight.
	2 30	....	.....	Campbell	
	2 30	....	.....	Los Gatos	East-west. Vertical, I. H. S.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
May 19, a.m.	2 32 10		II–III	Mt. Hamilton	East-west, W. W. C.
	3 30			do	
	4 47			Ferndale	Very slight shock, J. A. S.
	11 30			Los Gatos	I. H. S.
May 19, p.m.	2 30			do	
	11 56			Fort Bragg	
				Blocksburg	No time given.
May 20, a.m.	2 35			Carson City	Light. West-east, C. W. F.
May 20, p.m.	9 05			Fort Bragg	
	11 00			Los Gatos	I. H. S.
May 21, a.m.	5 30	3		Mile Rocks	Moderate.
May 21, p.m.	2 00			Los Gatos	I. H. S.
	4 50		III	S. F. Peninsula	
	12 00			do	
May 22, a.m.				Los Gatos	No time given, I. H. S.
				Ferndale	Before daylight. Very slight, J. A. S.
May 22, p.m.	12 30			Bartlett Springs	"The tremor might have been due to thunder."
May 23, a.m.	5 30			Los Gatos	I. H. S.
May 24, a.m.	1 30			do	I. H. S.
May 24, p.m.	1 28			do	I. H. S.
	8 45			do	I. H. S.
	11 17	2½		Bonita Point	Nearly vertical. Direction NE. No tremor, just a jar. 1 max. strongest at beginning. Sound like clap of thunder 2 s. before. May have been blasting.
May 25, a.m.	12 58	45–50		Berkeley	At Faculty Club. First irregular, then rhythmic and slow, then more rapid. During rhythmic part was able to recognize a distinctly east-west direction, and thought this changed later to north-south, but not quite sure, G. K. G.
May 25, p.m.	10 21	60		do	Began with confused irregular motion, but middle and final portions definitely rhythmic. I tried without use of watch to estimate period of rhythm, and think it was between 2 and 3 beats of the second, G. K. G.
May 27, a.m.	Early			Los Gatos	I. H. S.
	5 00			Santa Cruz	Slight shock.
May 28, a.m.	1 00			Los Gatos	I. H. S.
	1 05			do	I. H. S.
	4 06			do	I. H. S.
May 28, p.m.	10 45			Santa Cruz	
May 30, p.m.	12 37 20?			San Francisco	Light, A. G. McA.
May 31, a.m.	Early			Los Gatos	I. H. S.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
May 31, a. m.	5 45			Napa	W. H. M.
	5 49 54			Berkeley	R. T. C. in bed. Short and sharp.
	5 50			San Francisco	Light, A. G. McA.
	6			Peachland	
June 3, a. m.	8 25			Los Gatos	I. H. S.
	9 17			do	
June 4, p. m.	9 40			Ferndale	Very slight, J. A. S.
	11 40	2		Mile Rocks	
	11 50			Los Gatos	Rotary, I. H. S.
	11 50			Campbell	Sharp.
	11 50 50	3	III	Oakland	Chabot Observatory. Southwest to northeast.
	11 51			Mills College	
	11 51 07	60 +	IV–V	Berkeley	Ewing seismograph.
	11 51 45			do	A. O. L.
	11 52			San Francisco	A. G. McA.
				Napa	No time given.
	11 55			Niles	
June 5, a. m.	9 50			Los Gatos	I. H. S.
June 5, p. m.	11 55			Niles	
June 7, a. m.	12 21 39			Berkeley	A. O. L.
				Eureka	No time given.
				Upper Mattole	Heavy. No time given.
June 7, p. m.	4 10			Blocksburg	
	4 13	15		Ferndale	Slight, J. A. S.
	4 15			Fort Bragg	
	4 15	26		Eureka	South of west to east. Sudden, increasing, then dying. Shook buildings. Severest since April 18, A. H. B.
June 8, a. m.	5 15			Fort Ross	
	9			do	
June 8, p. m.	6 15	1		Mile Rocks	Slight.
June 9, a. m.	11 35			Fort Ross	
	11 56			do	
June 9, p. m.	7 40			Mills College	
	7 41			San Francisco	A. G. McA.
June 10, p. m.				Eureka	No time given.
	4 00			Los Gatos	I. H. S.
	6 26	2		Ferndale	Slight shock, J. A. S.
	9 11			San Francisco	
				Napa	No time given.
June 11, a. m.	4 30 Ship's time	10		Coronel Bay, South America	S.S. *Assuan*. Sharp shock.
				Napa	No time given.
June 12, p. m.	2 ±			Los Gatos	
June 13, a. m.	11 50			Eureka	Very light shock.
				Tequisquita Ranch	No time given.
				Campbell	No time given.
	11 51			Ferndale	Very light, J. A. S.
June 14, a. m.	4 50			do	Very light, J. A. S.
June 14, p. m.	5 55			Los Gatos	

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
June 14, p m.	5 56			Los Gatos	
	11 35			do.	
June 15, a.m.	3 40			Fort Bragg	
	6 11 50			Mt. Hamilton	E. S.
June 15, p m.	12 05			Los Gatos	
	12 09			do.	
	9 20			Sonoma	
	9 25	5		Mile Rocks	Moderate.
	9 39 35			Berkeley	Omori seismograph, east-west. Component 79 ± 10; north-south component 76 ± 10.
	9 39 45	3	III	Oakland	Chabot Observatory. From northeast.
	9 40			Sonoma	
	9 40 52		II	Berkeley	East-west 2 shocks, 1 s. apart, A. O. L.
	9 41			San Francisco	A. G. McA.
	9 41			Los Gatos	
	9 41			Mills College	
	9 41 52			Berkeley	R. T. C.
	9 42			Niles	W. B.
	9 45			Livermore	
	9 51 39		I	Berkeley	A. O. L.
	10 30	2		Mile Rocks	Slight.
	10 32 04	12		Berkeley	Omori seismograph, east-west component.
		17		do.	Omori seismograph, north-south component.
	10 35			San Francisco	A. G. McA.
				Peachland	No time given.
				Napa	No time given. Three shocks reported, W. H. M.
June 16, a m.	9 15			Los Gatos	I. H. S.
				Peachland	No time given.
June 16, p.m.	4 50			Ferndale	Light, J. A. S.
	11 50			do.	Light, J. A. S.
June 18, a.m.				Fort Ross	No time given.
June 20, a m.	8 10			Ferndale	Very light, J. A. S.
June 22, a.m	6 07			San Francisco	A. G. McA.
				Kentfield	No time given.
				Mt. Tamalpais	No time given.
June 22, p m	11 40	4		Mile Rocks	Slight.
	11 51 10	8	II–III	Berkeley	Principally vertical. Slight, tremors for 5 m. afterwards, no rumble, R. T. C.
	11 51 03	24		do.	Omori seismograph, east-west component.
		24		do.	Omori seismograph, north-south component.
June 25, a.m.	9 16	6		Ferndale	Light, J. A. S.
June 26				Napa	No time given.
				Peachland	No time given.
June 27				Fort Ross	No time given.
June 28				Peachland	No time given.
June 30				Upper Mattole	No time given. About the one hundredth shock since April 18, W. H. Roscoe.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
July 1	.. ..	....	.....	Mt. Tamalpais	No time given.
July 2	5 45	....	.....	Fort Bragg	a.m. or p.m. not given.
July 4, a.m.	5 35	....	.....	Los Gatos	I. H. S.
	5 39	....	I	Mt. Hamilton	East-west, E. A. F.
	5 45	....	.....	Campbell	
	5 45	....	.....	Salinas	
July 4, p.m.	1 15	....	.....	San Francisco	A. G. McA.
	1 15	....	.....	Los Gatos	I. H. S.
	10 45	....	.....	do	I. H. S.
July 6, a.m.	10 32	1	.....	Mt. Hamilton	Two light shocks. Three vibrations, R. G. A.
July 6, p.m.	10 52	....	.....	Salinas	
	10 52 15 ± 2	198	.....	Berkeley	Omori seismograph, east-west component. (North-south dismounted.)
	10 55	....	.....	Mt. Hamilton	Light. East to west, R. G. A.
	10 58	....	.....	Los Banos	
	.. ..	....	.....	San Luis Obispo	No time given.
July 7, a.m.	4	....	.....	Berkeley	Uninterrupted trembling until 6 a.m., R. T. C. and H. F. R.
July 9, p.m.	10 00	....	.....	Eureka	
	11 30	....	.....	Los Gatos	Rotary. Vertical, I. H. S.
	11 37	....	.....	Eureka	
	11 40	....	.....	Ferndale	Very light, J. A. S.
July 12, a.m.	.. ..	....	.....	Mt. Tamalpais	No time given.
	5 38?	....	.....	San Francisco	A. G. McA.
July 13, a.m.	5 20	....	.....	Sierra Madre	Moderate, U. S. W. B.
	5 30	....	.....	Los Angeles	
	5 35	....	.....	Newhall	
July 16, a.m.	12 10	....	.....	Los Gatos	Northwest-southeast, I. H. S.
July 17, p.m.	3	3	IV	Palo Alto	About 3 p.m.
July 18, a.m.	3 10	....	.....	Los Gatos	I. H. S.
July 18, p.m.	6 27 35	....	.....	San Francisco	A. G. McA.
July 20, a.m.	1 00	4	.....	Mile Rocks	Slight.
	1 19 36	35.3	III	Berkeley	Omori seismograph, north-south component.
		35.3	.....	do	Omori seismograph, east-west component.
	1 19 42 ± 2	....	III	do	Sudden jerk apparently from east-west with tremor lasting 3 to 4 s. Awakened from sound sleep, A. O. L.
	1 20	....	.....	do	Sharp shock. Dr. J. E. M.
	.. ..	....	.....	Mt. Tamalpais	No time given.
	1 20	....	.....	San Francisco	A. G. McA.
July 21, p.m.	10 10	....	.....	Los Gatos	North-south. Vertical, I. H. S.
	.. ..	....	.....	San Luis Obispo	No time given.
July 22, a.m.	9 15	....	.....	85 ml. N 86° W. from Cape Mendocino	Slight shock reported by Capt. J. R. Sarrins of schooner *Espada* in Lat. N. 40° 33′, Long. W. 126° 15′.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
July 22, a.m.	9 30.......	6.....	.....	85 mi. N. 86° W. from Cape Mendocino	Lat. N. 40° 33′, Long. W. 126° 15′.
July 22, p.m	10 39 30....	60 ±	II	San Jose.........	Horizontal, H. F. R.
	11 48 20....	....	.....	do..........	Horizontal and vertical motion, H. F. R.
July 23, a.m.	5 41.......	....	II	San Jose.........	H. F. R.
	11 25.......	....	.....	Los Gatos.........	I. H. S.
	.. ..	....	.....	Mt. Tamalpais....	No time given.
July 23, p.m	12 10.......	....	.....	Los Gatos.........	I. H. S.
	11..........	....	.....	Helen Mine.......	
	4 12.......	....	.....	Los Gatos.........	I. H. S.
July 24, p.m.	6..........	....	.....	Imperial.........	
July 25, p.m.	11 04 30 ±	60 ±	II	San Jose.........	H. F. R.
July 26, a.m.	4 37 30 ±	30 ±	II	do..........	H. F. R.
July 26, p.m.	9 18 30....	34.....	.....	Berkeley.........	Omori seismograph, east-west component.
	.. ..	19.....	.....	do. (Same record.)	Omori seismograph, north-south component.
	9 20.......	....	.....	Mills College......	
July 27, p.m.	10 10.......	....	.....	Point Loma......	
July 28, a.m.	12 22 40....	40.....	II	Berkeley.........	H. F. R.
	5 25.......	....	II	do..........	H. F. R
	5 44.......	....	II	do..........	H. F. R.
	6 01.......	....	II	do..........	H. F. R.
	7 25.......	....	II	do..........	H. F. R.
	7 46.......	....	II	do..........	H. F. R.
	.. ..	....	.....	Mt. Tamalpais....	No time given.
July 29, a.m	6 46.......	20.....	II	Berkeley.........	H. F. R.
July 30, a.m.	5 35.......	....	II	do..........	H. F. R.
	.. ..	....	.....	Eureka...........	No time given.
Aug. 1, a.m.	6..........	....	.....	Peachland........	Light.
	11 31.......	....	.....	Ferndale.........	Very light, J. A. S.
	11 32.......	2.....	.....	Eureka...........	Vibration from southwest.
	.. ..	....	.....	San Luis Obispo..	No time given.
Aug. 2, a.m.	6 04.......	....	.....	Fort Ross........	G. W. C.
	6 10.......	....	.....	Plantation.......	Hard. Rumbling noise from ocean for 2 days.
	6 14–15....	....	.....	do..........	Slight.
	6 15 ± 5m..	....	.....	Berkeley.........	Omori seismograph. Duration, east-west component 2 m. 48 ± 10 s. Duration, north-south component 1 m. 36 ± 10 s.
Aug. 3, p.m	5..........	....	.....	Plantation.......	Heavy, followed by slight shock.
	5 03.......	....	.....	Fort Ross........	G. W. C.
	7 05.......	40.....	.....	Gulf of California	Lat. N. 25° 35′, Long. 110° 06′ W. Ship *Alex Gibson*. Very heavy shock.
	7 10.......	15.....	.....	do..........	Lighter shock.
	Between 8 and 12...	....	.....	do..........	Two more shocks, very light.
	11..........	....	.....	Plantation.......	Heavy.
Aug. 4, a.m.	5 39.......	....	I	Mt. Hamilton....	

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Aug. 4, p.m.	11 19		II	Berkeley	Faculty Club, slight vibrations, H. F. R.
Aug. 5, a.m.	1 50			Fort Ross	G. W. C.
	1 53		II	Berkeley	Faculty Club, slight vibrations, H. F. R
	3 25		II	do.	Faculty Club, slight vibrations, H. F. R.
	6 15		II	do.	Faculty Club, slight vibrations, H. F. R.
Aug. 6, a.m.	10 32 2		II	Mt. Hamilton	
Aug. 8, p.m.	5 56–57m			Los Gatos	I. H. S.
	6 13			do.	I. H. S.
Aug. 12, a.m.	6 00			Rio Vista	
Aug. 14, a.m.	8 30			Salinas	Light.
	9 35			do.	Light.
Aug. 15, a.m.	2 07 15	25		Berkeley	Omori seismograph in east-west component.
	4 40			Tequisquita Rancho	
Aug. 16, p.m.	4 17 58			Berkeley	Omori seismograph. Duration $1^h 40^m$.
	7 45 ship's time	3 m.		Coronel Bay, S. America	SS. *Rameses.*
Aug. 19, a.m.	1 59			Salinas	Sharp.
	2			Tequisquita Rancho	Tremor and jolt, A. G. McA.
	9			San Francisco	
Aug. 21, p.m.	12 15	1 m.		Lat. N. 26° 19′ Long. 110° 25′	Gulf of California. Heavy. Bark *St. James.*
Aug. 22, a.m.	1 55			Napa	W. H. M.
Aug. 25, p.m.	1 40			Ferndale	Light shock, J. A. S.
Aug. 26, p.m.	9 09	3		do.	Light shock, J. A. S.
Aug. 27, a.m.	10			Point Loma	
Aug. 28, a.m.	3			Ferndale	J. A. S.
	11 40			Tequisquita Rancho	
Aug. 29, a.m.	7 59 35	2		Mt. Tamalpais	Southeast-northwest, W. W. Thomas.
Aug. 30, a.m.	2 12			Sonoma	
Aug. 31, a.m.	3 12			do.	
	9 52			Fort Ross	
Sept. 1, a.m.	3 12			Sonoma	Light shock.
	5 50			Tequisquita Rancho	
Sept. 2, a.m.	3 45	1 m.		Lat. N. 43° 40′ Long. W. 128° 50′	Bark *Agate.* Heavy. 100 miles west of Coos Bay.
	3 55			Lat. N. 43° 40′ Long. W. 128° 50′	Not so severe.
Sept. 6, a.m.	12 10			Branscomb	A. J. Haun.
Sept. 7, a.m.	6 37	5–10		San Francisco	Very faint, G. K. G.
	9 21 59	10	II–III	Mt. Hamilton	Perceptible vibration. One slight shock. East to west.
	9 30			Santa Cruz	

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Sept. 8, p.m.	12 32.......	20-30..	.....	Berkeley.........	Faculty Club. To and fro motion with period of about 0.5 s., but closed with irregular fluttering motion, G. K. G.
Sept. 9, a.m.	4 15.......	....	.....	Grass Valley.....	Southeast-northwest, J. Sanks.
	4 55.......	....	.....	Carson City.......	C. W. F.
	4 55.......	....	.....	Pilot Creek.......	E. W. Stanton.
	5..........	....	.....	Nevada City.....	S. W. Marsh.
	5..........	....	.....	Wabuska, Nev....	Tremor, J. G. Young.
Sept. 13, a.m.	11..........	....	.....	Lat. N. 43° 02'... Long. W. 125° 41'	Bark *Palmyra*, 48 miles W. of Cape Orford.
Sept. 13, p.m.	8 45.......	....	.....	Ferndale.........	Short, J. A. S.
Sept. 14, a.m.	8 46	44 m...	.....	Berkeley.........	Omori seismograph, east-west component (origin probably 435 mi. distant).
	.. ..	25.....	.....	Lat. N. 41° 78'... Long. W. 125° 52'	85 mi. NW. Cape Mendocino. (No time.) Schooner *Robert Searle*.
Sept. 16, a.m.	7 12 2.....	....	III?	Mt. Hamilton....	Several observers give north to south. Duplex showed E. 20° S.
Sept. 17, p.m.	5 15.......	10.....	.....	Ferndale.........	J. A. S.
	8 10	....	.....	do..........	J. A. S.
Sept. 18, p.m.	8 45	....	.....	do..........	J. A. S.
Sept. 20, p.m.	2 20.......	....	.....	Mare Island......	From 20° W. of S. movem't ¾ s.
	11 39.......	....	.....	Berkeley........	Faculty Club. Slight, G. K. G.
Sept. 21, p.m.	11 24.......	....	.....	do..........	Faculty Club. Slight, G. K. G.
Sept. 25, a.m.	5 36.......	....	.....	do..........	Faculty Club. Slight, G. K. G.
Sept. 25-26	.. ..	....	.....	Mare Island......	From 5° W. of S. movement ¾ s. (No time.)
Oct. 5, a.m.	6 30.......	....	.....	San Francisco....	
Oct. 7, p.m.	11 57.......	....	.....	Fort Ross........	G. W. C.
Oct. 10, a.m.	5 45.......	....	.....	Tequisquita Rancho	
Oct. 10, p.m.	11 45.......	....	.....	San Francisco....	
Oct. 11, a.m.	5 30.......	....	.....	Salinas...........	
Oct. 15, p.m.	2 49.......	....	.....	Berkeley.........	Omori seismograph.
Oct. 17	.. ..	....	.....	Fort Ross........	During night, G. W. C.
Oct. 18, a.m.	5...........	....	.....	Tequisquita Rancho	
Oct. 24, a.m.	8 45 10....	....	.....	Berkeley.........	Omori seismograph.
Nov. 4, a.m.	11 58.......	....	.....	Fort Ross........	
Nov. 6.	.. ..	2-3...	.....	Lat. N. 46° 09'... Long. W. 125° 22'	No time given. Sharp, followed by 3 mountainous waves 55 mi. W of Cape Disappointment Schooner *Stanley*.
Nov. 7	....	....	.. ...	Eureka..........	No time given.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Nov. 9, a.m.	2			Fort Bragg	
Nov. 11, a.m.	6 40 ship's time			Lat. N. 42° 51′ Long. W. 127° 51′	Ship received a quick rolling motion, and a few seconds after trembled fore and aft. Bark *Carondelet*.
Nov. 12, a.m.				Salinas	Light.
Nov. 13, a.m.				Fort Bragg	
Nov. 13, p.m.	7 47 49			Mt. Hamilton	One jolt. North to south.
	7 48			Glenwood	
	7 48			Tequisquita Rancho	
	7 48	3		San José	Sharp. East to west.
Nov. 14, a.m.	2 30			Fort Bragg	
Nov. 14–15				Fort Ross	During night.
Nov. 16, a.m.	12 30			Berkeley	Short tremor, G. K. G.
Nov. 22, p.m.	3 53			Glenwood	
	10 45			Isabella	
Nov. 25, p.m.	1 15			San Francisco	Very light.
Nov. 26, a.m.				do.	No time given.
Nov. 26, p.m.	10 27	8–10		Lat. N. 14° 41′ Long. W. 92° 36′.	Sharp shock. About 20 mi. off coast of Guatemala. S. S. *Newport*.
Dec. 2, a.m.	1 19			Berkeley	First stronger, G. K. G.
	2 23			do	Increasing in strength, with regular horizontal oscillation with period estimated at about 0.5 s. Became irregular toward end, giving sense of fluttering, but superposed on the irregular motion was a regular beat with an estimated period of 1 s., G. K. G.
Dec. 6, a.m.	6 45			Tequisquita Rancho	
				San Luis Obispo	No time.
Dec. 7, p.m.	10 55			San Miguel	
Dec. 8, a.m.	10 40			Idyllwild	
Dec. 8, p.m.	5 48 54	2		Mt. Tamalpais	Light shock.
Dec. 9, a.m.	3 20		III	San Francisco	Duration a few seconds. One marked wave southwest to southeast, A. G. McA.
	3 20			Mills College	J. Keep.
	3 20	20		Berkeley	Southwest-northeast.
	3 20 40	6		Oakland	Light, C. B.
Dec. 19, p.m.	2 46			Escondido	
	3			Cuyamaca	
Dec. 22, a.m.	8 45			Calexico	
Dec. 23, a.m.	4			Cuyamaca	
	4 55			Calexico	
	5 48			Fort Ross	
	9 26 35			Berkeley	Omori seismograph, east-west component only.

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Dec. 24, a.m.	2			Napa	Sharp jar.
Dec. 25, p m	8 15			Rohnerville	
	8 18			Eureka	
Dec. 28, a m.				Lytle Creek	In the early morning. Light.
1907. Jan., 1 p.m.	11 00			Kentfield	
Jan. 4, a.m.	3 20			Santa Cruz	Regular rocking motion. First north-south, F. L.
Jan. 5, p.m.	5 to 6			Fort Ross	
Jan. 6, a. m	3 15			Salinas	
Jan. 7, p.m.	9 20			Idyllwild	
	10 48 55				
	11 03			Berkeley	Omori seismograph.
	11 05	4		do	G. K. G.
				Santa Cruz	First shock, then short, ominous lull, followed by quick, vicious shaking and twisting, which lasted not more than 4 s. Seemed to come from northwest, F. L.
	11 05			Campbell	Sharp. No damage.
	11 05			Niles	
	11 05			Salinas	
	11 10			Los Gatos	I. H. S.
	11 10			San Francisco	
	11 20			Glenwood	
				Boulder Creek	Hour not given.
Jan. 8, p.m.	3 45		VI	Santa Cruz	Sharp jolt, F. L.
	4 31 36	10		Berkeley	Omori seismograph, east-west component only.
Jan. 9, p.m.	12 39 42	101		do	Omori seismograph, north-south component only.
Jan. 10, p m	3 21			Idyllwild	
Jan. 13, a.m.	4 50			Blocksburg	
Jan. 14, a.m.	4 50			Eureka	Light.
Jan. 14, p.m.	4 23 35			Berkeley	Omori seismograph, north-south component only. Duration 18 m. 15 s.
Jan. 18, p.m.	11 45			Idyllwild	
Jan. 19, a.m.	7 05			Isabella	Light.
	9 36 00	24		Berkeley	Omori seismograph, north-south component.
	9 35 45	23		Berkeley	Omori seismograph, east-west component.
Jan. 23, a.m.	10 53	7		do	Omori seismograph, east-west and north-south components
Jan. 25, a.m.	9 25 38	90		do	Omori seismograph, north-south component only.
	10 39 50	60		do	Omori seismograph, north-south component only.
	10 56 12	133		Berkeley	Omori seismograph, north-south component only.

Record of after-shocks—Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Jan. 25, p m	3 24 18			Berkeley	Omori seismograph, north-south component.
	3 24 18			do	Omori seismograph, east-west component.
	3 57 18			do	Omori seismograph, east-west and north-south components.
Jan. 26, a m	10 13 47	27		do	Omori seismograph, north-south component.
	10 14 08	10		do	Omori seismograph, east-west component.
	10 24 49	30		do	Omori seismograph, north-south component only.
Jan. 28, p m	2 42 18	39		do	Omori seismograph, north-south component only.
	4 16 54			do	Omori seismograph, north-south component. Slight irregular shifts.
	4 18 44			do	Omori seismograph, east-west component.
Jan. 29, p m	5 00 32			do	Omori seismograph, north-south component.
	5 00 32			do	Omori seismograph, east-west component.
Jan. 30, p m	2			Kentfield	
	2 41 11			Berkeley	Omori seismograph. Both components.
	3			San Francisco	
Jan. 31, a m	12 30			Kentfield	
	0 27			Mills College	
	12 30			Sonoma	Light.
	12 30 18	64		Berkeley	Omori seismograph, north-south component.
	12 30 32	86		do	Omori seismograph, east-west-component.
	12 33			Niles	
	12 33			San Francisco	
	12 35			San Jose	Sharp.
	12 35			Napa	
	12 36 06		III	Berkeley	Awoke people in my house, R. T. C.
				Boulder Creek	No hour given.
Feb. 3, a m	10 30	8		Lat. N. 37° 35′	Neither shock was violent, but a decided trembling motion east-west, 28 geo. mi. S. 73° W. from SE. Farallon, Schooner *Melrose*.
	10 50	5		Long. W. 123° 35′	
Feb. 3, p.m.	7 55			Livermore	
Feb. 5, a.m.	4 25			La Porte	
Feb. 13, a.m.	10 50			Livermore	
Feb. 14, a m	6 45			do	
Feb. 16, a m	2 09 30			Point Loma	
Feb. 25, a m	5 16 40			Eureka	

Record of after-shocks — Continued.

Day.	Beginning of shock.	Duration.	Intensity.	Locality.	Remarks.
	h. m. s.	secs.			
Mar. 11, p m	11 58	20	.....	Berkeley	Faculty Club. In bed at time, 3 phases. First more than one-half total time, rapid tremor. Period averaging less than 0.25 s. Second about one-half total time. Higher intensity. Motion less irregular, period estimated at 0.5 s. Third, comparatively short. Motion irregular. Average period shorter than second phase. Intensity at first same as second phase, but rapidly declined, G. K. G.
Mar. 24, a.m.	5 56 04	....	.....	do	Omori seismograph, north-south component.
	5 56 06	....	.....	do	Omori seismograph, east-west component.
Mar. 30, p.m.	2 28 22	17	.....	do	Omori, north-south component.
	2 28 22	9	.....	do	Omori, east-west component.
Apr. 14, p.m.	10 40.0	21 0	.....	do	Omori, north-south component.
	10 32.2m	37 2	.....	do	Omori, east-west component.
May 12, a.m.	10 21 31	26	.....	do	Omori, north-south component.
	10 21 31	24	.....	do	Omori, east-west component.
June 5, a m.	12 26 37	03	.....	do	Omori, north-south component.
	12 26 37	53	.....	do	Omori, east-west component.
	12 26 36	35	IV–V	do	Observatory, R. T. C.
	12 26 41	....	.....	do	Observatory, S. E.
June 10, a.m.	9 47 51	1 47	.....	do	Omori, north-south component.
	9 47 51	2 32	.....	do	Omori, east-west component.
	9 47 55	....	.....	do	At Faculty Club, S. E.
	9 48 05	30	.....	do	At home. Asleep, A. O. L.
	9 47 47	....	III	do	2011 Bancroft Way, R. T. C.
	11 10 48	....	.....	do	Omori. (Doubtful shock.)

KEY TO INITIALS.

R. G. A. = R. G. Aitken
S. A. = S. Albrecht
W. B. = William Barry
A. H. B. = A. H. Bell
C. B. = Charles Burkhalter
K. B. = K. Burns
G. W. C. = G. W. Call
W. W. C. = W. W. Campbell
R. T. C. = R. T. Crawford
N. E. = Nelson Eckart

W. R. E. = W. R. Eckart
S. E. = S. Einarson
E. A. F. = E. A. Fath
C. W. F. = C. W. Friend
G. K. G. = G. K. Gilbert
A. M. H. = Adelaide M. Hobe
J. N. LeC. = J. N. LeConte
A. O. L. = A. O. Leuschner
F. L. = Finette Locke
J. D. M. = James D. Maddrill

W. H. M. = W. H. Martin
A. G. McA. = A. G. McAdie
B. L. N. = Burt L. Newkirk
C. D. P. = C. D. Perrine
J. G. P. = J. G. Plummer
H. F. R. = H. F. Reid
J. A. S. = J. A. Shaw
E. S. = E. Smith
I. H. S. = Irving H. Snyder
S. D. T. = S. D. Townley

COMPARISON WITH OTHER SEVERE EARTHQUAKES IN THE SAME REGION.

THE EARTHQUAKE OF 1868.

The earthquake of October 21, 1868, was most severely felt in the region about San Francisco Bay, particularly on the east side in the vicinity of Haywards. The time of its occurrence is variously stated from $7^h 47^m$ to $7^h 54^m$ A. M. It gave rise to disasters in the city of San Francisco, and some people recalling the event vividly are of the opinion that the shock was as severe as that of April 18, 1906. Early in the investigation of the latter earthquake, it became apparent that the relationship of the two earthquakes would be an essential part of the inquiry. Shortly after the earthquake of 1868 a committee of scientific men undertook the collection of data concerning the effects of the shock, but their report was never published nor can any trace of it be found, altho some of the members of the committee are still living. It is stated that the report was supprest by the authorities, thru the fear that its publication would damage the reputation of the city. Our knowledge of that earthquake is therefore not very full, and is contained chiefly in the newspaper reports of that day. A summary of this data is given in Holden's Catalogue of Earthquakes,[1] and by Griesbach.[2]

With the object of supplementing the facts regarding the earthquake of 1868 recorded by Holden, for the purpose of comparing it with that of 1906, an inquiry was started and intrusted to Mr. A. A. Bullock. This gentleman has reviewed the periodicals of the time, and has interviewed many people who experienced the shock. He has also examined the region of maximum intensity, and has had, on several of his trips, the guidance of old residents. In response to a request by the Commission, several people have written an account of their experiences at the time of the earthquake of 1868. In this way a considerable body of valuable information has been gotten together, which supplements to an important degree the extant accounts of that earthquake.

THE FAULT-TRACE.

It appears from Mr. Bullock's inquiries that the earthquake of 1868 was due to an earth-movement along the base of the hills which overlook San Francisco Bay on the east, and which are often referred to, particularly farther north, as the Berkeley Hills. These hills present a remarkably even, straight front, and without doubt represent a degraded fault-scarp. Along the base of this scarp a crack opened on the morning of October 21, 1868. This crack is regarded as the trace of the fault which caused the earthquake. Its position has been determined at intervals along a nearly straight line from the vicinity of Mills College, east of Oakland, to the vicinity of Warm Springs near the Santa Clara County line; but the evidence of its existence to the northward of San Leandro is not very satisfactory. The county was then unsettled, and the information consisted of reports of cow-boys riding the range. From San Leandro southeastward, however, the evidence is full and conclusive. The general trend of the fault is northwest-southeast; or, to be more exact, N. 37° W., a bearing almost the same as that of

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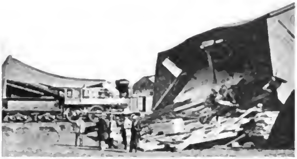
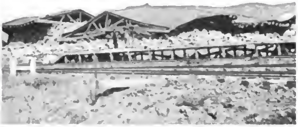
[1] Smithsonian Misc. Coll., vol. xxxvii, 1898.

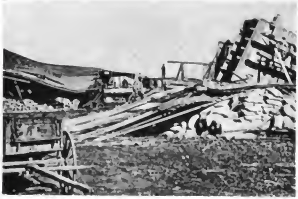
[2] Mitt. d. k. k. Geograph. Gesellsch. in Wien, Band xii, 1869, pp. 223-231.



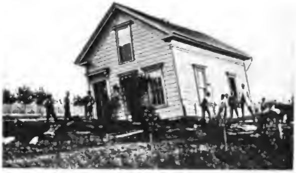
A. Flour mill, Haywards. Wrecked by earthquake of 1868.



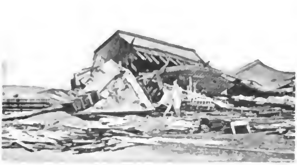
B. Edmonson's warehouse, Haywards. Wrecked by earthquake of 1868.



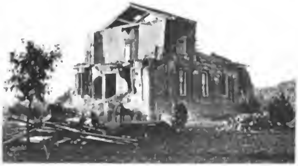
C. Flour mill and warehouse, Haywards. Wrecked by earthquake of 1868.



D. Pierce's house, Haywards. Earthquake of 1868.

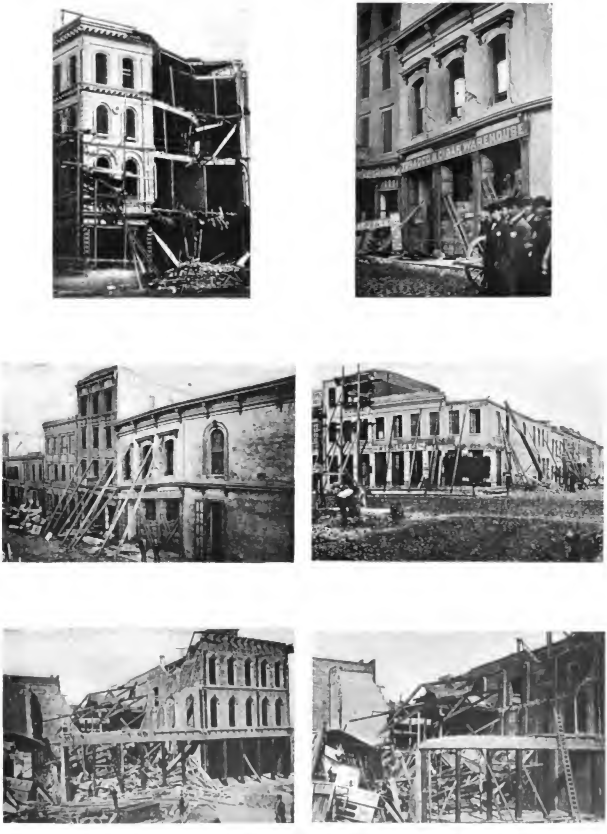


E. Haywards. Wreck of buildings by earthquake of 1868.



F. Court-house, San Leandro. Wrecked by earthquake of 1868.

From photographs preserved by Mr. H. Bendel.



Effects of the earthquake of 1868 in San Francisco. From photographs preserved by Mr. H. Bendel.

the fault-trace of 1906 along the San Andreas Rift. The position of this fault-trace is shown on map 4. While in general it lies along the base of the old degraded scarp, it is still, for the most part, within the hill-slopes and not in the alluvium which extends from the base of the hills. In some places where it crost the lower ground, the crack showed faulting or displacement of 8 or 10 inches, but from the accounts given it is not clear in what direction the faulting took place. The statements indicate a slight downthrow on the southwest side. In other places a displacement of 3 feet is said to have been observed. In places the crack along the fault-trace opened to a very considerable depth with a width of 10 or 12 inches, and remained open until filled with falling earth. On the higher ground of the hill-slopes no open crack was observed; there was merely the trace of the rupture in the sod. This fault-trace could be followed at intervals for 20 miles southeast from San Leandro, and it had a straight course without regard to the contour of the hills. In some places it was quite at the bottom of a hillside, while at other places it was high on the slope; and on at least one low hill it past near the top thru a saddle-like depression. Springs are common along the base of the hills, and the fault-trace was above the springs. According to the testimony of old residents the flow was not affected by the earth-movement.[1] In the hills to the northeast of the fault-trace, however, new springs were started and old ones revived, altho some few ceased flowing.

That the crack extended down into the bedrock is testified to by many who observed closely. Three men reported that they tried to sound the bottom of the crack, but were unable to do so. In the vicinity of Haywards it is reported that there were two branch cracks from the main one, trending off into the hills. Water and sand were ejected from the crack in one place.

Between Decoto and Niles the crack left the base of the hill front, and deviating slightly from its general trend thus far, crost the plain of the alluvial fan of Alameda Creek at the mouth of Niles Canyon to the foot-hills at the town of Irvington. For the greater part of this distance, it appeared as an open crack. It past thru a lagoon about 0.5 mile in length, following closely the longer axis of the depression, and the water of the lagoon was drained out, apparently into the crack. At Irvington the crack became coincident with the very straight and even ancient fault-scarp of the foot-hills southeast of that town. This ancient scarp has a strike of N. 38° W. Beyond this it was not observed farther than Aqua Caliente Creek.

Immediately to the east of Mission San Jose, entirely within the hills, another crack opened with a strike of N. 18° to 20° W., which, converging upon the crack thus far traced, extended south as far as the county line.

The greatest intensity of the earthquake was along the crack and in its vicinity. On the projection of this line southward into Santa Clara County, the intensity diminisht steadily as far as Morgan Hill, where it again rose. At Gilroy, Hollister, and San Juan, according to reports, the intensity was sufficient to throw down a few chimneys and to crack some brick and adobe buildings.

The greatest damage was done at Haywards, where nearly every house was thrown off its foundations; while at San Leandro the shock was less severe. (See plate 144.) A house near old Blair Park, in the present Piedmont district of Oakland, was badly damaged. The only other town of that date in close proximity to the fault-trace was Mission San Jose, which lies in the hills a few hundred yards west of it. In this town were several adobe buildings, one of which, a church, was wrecked. Many chimneys were thrown, but the general effect was much less severe than at Haywards.

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[1] The gentlemen who chiefly aided Mr. Bullock in tracing out this crack are Messrs. W. Smith, S. Huff, and McCarthy, of San Leandro; Messrs. O. Hill, F. F. Allen, F. Wrede, and H. V. Monsen of Haywards; Mr. Decoto, of Decoto; and Mr. W. Berry, of Niles.

In general, the direction of throw of objects was north or south. From several tanks the water slopt north and south. Nearly all the chimneys reported were thrown either north or south. Several frame houses were thrown south. One of these, 0.5 mile south of the line of the fault, was thrown 4 feet and another on the line was violently thrown 6 feet.

Several people report that rumblings preceded the shock, coming apparently from the south or southwest. Others saw a wave-like motion set up in the surface of the ground approaching from the south or southwest.

THE EFFECT OF THE EARTHQUAKE IN SAN FRANCISCO.

At San Francisco and nearby points the earthquake lasted for about 42 seconds. It was in general north and south.[1] A second shock followed the first at $9^h\ 23^m$ A. M., and lasted for 5 seconds, with the same direction as the first. Until about $12^h\ 15^m$ P. M., light shocks continued to be felt about every 30 minutes; and inside of the 24 hours immediately following the initial shock, 12 minor shocks were felt. The first indication of the approach of the earthquake was a slight rumbling sound, coming apparently from the direction of the ocean. The sound was heard very distinctly in the lower part of the city, but the residents on the hills do not appear to have heard it. (*San Francisco Times*, Oct. 21.) The shock commenced in the form of slow, horizontal movements. The oscillations continued from 10 to 15 seconds, growing more rapid and more violent for 6 or 7 seconds, then partially ceasing for 3 or 4 seconds, then increasing in force and rapidity for 4 or 5 seconds, then suddenly ceasing. (*Alta California*, Oct. 22, 1868.)

There were no abnormal barometrical changes at the time of the earthquake. No chronometer in Mr. Tennent's office was disturbed or showed any change of rate. The pendulum clock in his office was not stopt. A transit instrument erected on Russian Hill, belonging to him, was not disturbed in the slightest degree. Two magnets, one in his office and one in charge of a friend, showed no loss of magnetic power. One was loaded to its full extent, and the slightest loss of power would have permitted the weight to fall. (*Bulletin*, Oct. 22, 1868.)

The portion of the city which suffered most was that part of the business district, embracing about 200 acres, built on "made ground"; that is, the ground made by filling in the cove of Yerba Buena. (See plates 145 and 146.) The bottom of this cove was a soft mud varying from 10 to 80 feet in depth, and the material used to fill it was largely "dump" refuse, much of which is organic and hence perishable. Many of the buildings of that period were built flat on this filled mud, without piling, and before the land had had time to become firm. On this made land there was a very evident belt of maximum damage several hundred feet wide and running about northwest and southeast, commencing near the custom-house and ending at the Folsom Street wharf. One account of this belt goes so far as to trace 8 or 10 distinct lines of maximum disturbance, practically every building on these lines being more or less damaged, while none outside of these lines was seriously injured.

In many places the made land settled. At the junction of Market and Front Streets, the ground sank for a foot or two, and there was evidence that the tide had risen in the adjoining lot at the same time, for a pond of water collected and remained until low tide. On Pine Street, near Battery, the cobbles on the south side of the street sank away from the curbstones to the depth of 1 foot in some places; and the asphalt sidewalk on the north side was twisted and torn out of all shape, and its connection with the curb-stone severed. (*Alta California*, Oct. 22, 1868.)

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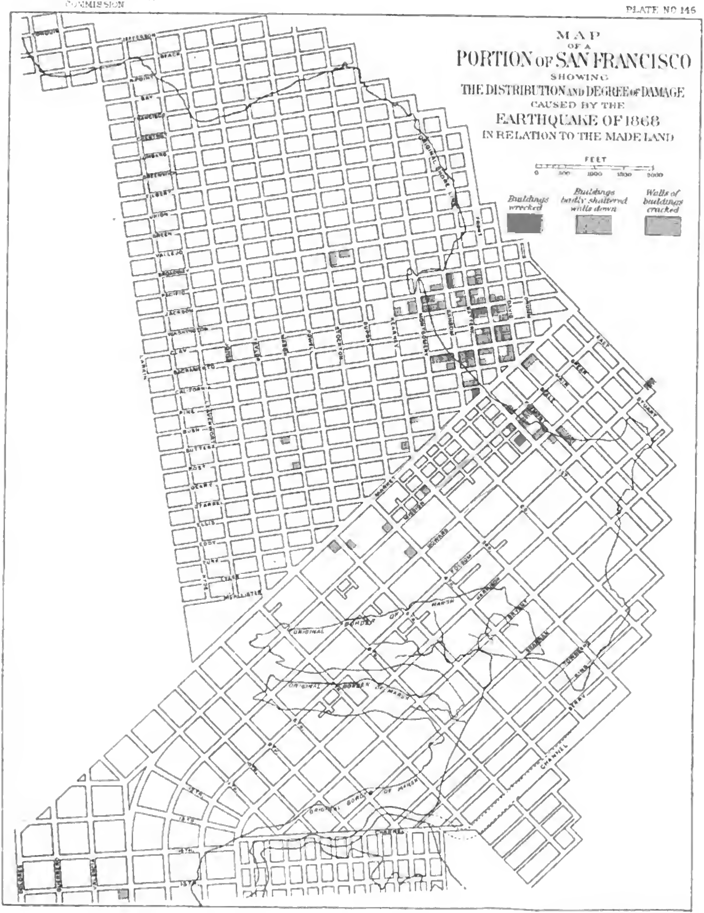
[1] Thos. Tennent, agent U. S. Coast Survey, in *Alta California*, on Oct. 22, 1868, reports it as lasting 46 seconds and as being from southeast to northwest (nearly) in direction.

EARTHQUAKE INVESTIGATION
COMMISSION

PLATE No. 145



MAP
OF A
PORTION OF SAN FRANCISCO
SHOWING
THE DISTRIBUTION AND DEGREE OF DAMAGE
CAUSED BY THE
EARTHQUAKE OF 1868
IN RELATION TO THE MADE LAND

JULIUS BIEN & CO. PHOTO. LITH. N.Y.

At the corner of First and Market Streets, the ground opened in a fissure several inches wide. At other places the ground opened and water was forced above the surface. (*San Francisco Bulletin*, Oct. 21, 1868.) At Fremont and Mission Streets the ground opened in many places. (*Alta California*, Oct. 22, 1868.) The general course of damage in the city was along the irregular line of the "made land," or low alluvial soil, where it met the hard or rocky base beneath it. Along the line of the old shore of Yerba Buena Cove, we found the damage to brick buildings much the largest. (George Davidson.) The custom-house, at the corner of Sansome and Clay Streets, was hurled south, by what seemed to be an undulating motion, and plaster fell. (*Bulletin*, Oct. 22, 1868.)

The outstanding portico on the east side of the custom-house was so badly shattered that it had to be removed; the main building stood fairly well, but one of the chimneys was broken across at the roof-line and turned thru an angle of over 45°. (George Davidson.)

The ground floor and the foundation of the old Merchants' Exchange appeared to have taken a different motion from the upper portion. The arch over the main corridor appeared to have been crusht. Just underneath the center, the matting was raised 2 inches. The corresponding arch at the south end of the corridor was also damaged, and there was a similar protuberance under the matting beneath it. Smaller arches at right angles to the main arches described were crusht in similar fashion. The north and south walls of the building, at the second floor, over the main arches, opened in large cracks. (*Bulletin*, Oct. 22, 1868.)

A 3-story brick structure on the corner of Market and Battery Streets, in an unfinished condition, was completely thrown down. Several different reports state, however, that it was very poorly constructed. In the Union Foundry, on First Street at the corner of Market Street, most of the machinery was displaced. (*San Francisco Bulletin*, Oct. 21, 1868.)

The floor of the Pacific foundry was raised about 2 feet in places. The center of Mission Street (opposite Fremont Street) exposed an opening from 8 to 10 inches wide; and openings of the ground were also plainly to be seen on Fremont Street, in the same vicinity. (*San Francisco Bulletin*, Oct. 21, 1868.)

Outside of the immediate district described above, damage to the rest of the city was very meager. It will be noticed in the following notes, and by a consultation of the map of San Francisco, plate 146, that the region of greatest agitation was confined to the low portions of the city, or the vicinity of some old creek bed or swamp.

The flat between Howard Street and Mission Bay was more severely shaken than Russian and Telegraph Hills; but the damage, save to chimneys and plaster, was slight. The only serious injury on Kearney Street was done to a building on the east side of the street. The building was an old one. At the corner of Fifth and Market Streets a fire-wall was thrown down. At the corner of Fourth and Bryant Streets, walls were cracked and damaged; Fourth Street near Bryant opened in places and at the crossing of Harrison and Fourth the railroad track settled about 8 inches, the planks between the rails rising about 10 inches. The Lincoln School-house (east side of Fifth Street near Market Street) was badly damaged, most of the chimneys being broken but none thrown down. The large statue of Lincoln in front of the building was ruined, but was not thrown off its pedestal. (*San Francisco Bulletin*, Oct. 21, 1868.)

The large chimney of the sugar refinery on Eighth Street fell in, crushing thru the ceilings. (Letter to *New York Times*, Oct. 21, 1868.)

A drug store at the corner of Fifth and Folsom Streets had its entire stock destroyed by falling. The chimneys of the Mission Street public school (west side of Mission Street between 15th and 16th Streets) toppled off some bricks. (*Alta California*, Oct. 21, 1868.)

A part of the brick walls of the new Calvary Church (Geary and Powell Streets) fell. A small crevice opened, as in 1865, on Howard Street beyond Sixth Street. No damage was sustained by the dry-dock at Hunter's Point. On the beach at the foot of Webster Street, below high-water mark, a fissure opened, extending lengthwise with the water. The stream of a sewer running from the Laguna to the foot of Webster Street into the bay, hitherto clear, immediately turned inky black. (*Alta California*, Oct. 22, 1868.)

The sugar refinery at North Point, a 7-story brick structure, surmounted by a tall brick chimney, was injured to the extent of losing 6 or 7 feet of its 100-foot chimney. A large fissure was made in the high bank near Fort Point and the shock was felt severely at the Fort. (*San Francisco Times*, Oct. 22, 1868.)

At the Cliff House nothing unusual took place, with the exception of a decided commotion in the ocean and an impetus given to the every-day wave which sent it well inland, say 15 or 20 feet above the usual mark. The shock, however, did no damage, not even upsetting any of the glassware in the bar. (*Alta California*, Oct. 22, 1868.)

Upon Russian and Telegraph Hills the shock was not very damaging. In some houses on the latter ornaments were not displaced from the mantel and the inmates did not come to the doors. In others, books and ornaments fell down and marble mantels were started from their places. The oscillations on Russian Hill were more severely felt. There was a pretty general stopping of clocks, some cracking of plaster, and throwing down of light articles. (*San Francisco Bulletin*, Oct. 21, 1868.)

A pail of water, two-thirds full, on the ground at the summit of Russian Hill, slopt over both sides. (*Alta California*, Oct. 22, 1868.)

The colored Masonic Hall, Stockton Street between Pacific and Broadway, a 2-story brick structure, was badly wrecked. (*San Francisco Times*, Oct. 22, 1868.)

From the meagerness of reports it is certain that no great loss was occasioned by the parting of water mains. The *Bulletin* for October 21 reports that the water at the Mission was shut off by the pipe being disconnected. In several parts of the city the water-pipes broke underground and caused some loss of water, but the water company soon had all repairs made. No fires are reported in the upper Mission district during the 24 hours following the earthquake. At Laguna Honda (a natural reservoir and the chief source of water supply, 2.5 miles west of Valencia and Market Streets) the water was violently agitated and the waves met in the center, throwing up a large jet several feet into the air. (*Alta California*, Oct. 22, 1868.)

The first alarm of fire was given shortly after 8 o'clock from Box No. 26 (northeast corner of Clay and Battery Streets). The fire was in Wellman and Peck's grocery (Front and Clay Streets) and was caused by matches. The chief damage was caused by water.

During the night following the earthquake, three fires occurred in the wholesale district, but there was no lack of water and all were quickly extinguished.

In the Fire Commissioner's report in the Municipal Records of San Francisco for 1868-1869, the following losses by fire are recorded: September, 1868, $24,229; October, 1868, $133,564.46; November, 1868, $19,920; December, 1868, $82,019.

The force of the shock was distinctly felt on the bay and as far as 15 miles west of the heads, but no great agitation of the water is reported. The tide-gage at one of the Government stations indicated no unusual rising of the tide. (*San Francisco Times*, Oct. 22, 1868.)

There was no tidal wave accompanying the earthquake. The passengers on a ferry steamer (off Angel Island) felt the shock and supposed for the time that they were aground. Many other boats reported the same experience. Two boatmen in a Whitehall boat off Fort Point report a heavy rumbling sound coming from the water. Their boat was shaken and whirled rapidly around (before the rollers reached them) and shortly they met 3 heavy rollers coming from the northwest on a calm sea. (*Alta Cali-*

fornia, Oct. 22, 1868.) The shock of the earthquake was distinctly felt at sea near San Francisco. Captain Tobey, of the ship *Pactolus*, reported being at anchor in deep water about 15 miles west of the Heads when the shock took place. At first it seemed as if the vessel were passing over a coral shoal and striking quite heavily. The noise and motion made it seem as if the ship were dragging, with her chains also slipping out. (*San Francisco Bulletin*, Oct. 22, 1868.) The ship *Cesarewitz* felt the shock nearly out at the Farallones; the brig *Orient*, bound in, 8 miles out, experienced the shock heavily. Pilot Murphy, on a transport bound out, reported that the bark seemed to have struck bottom, her progress being impeded; and the ship, especially the yards and masts, trembled violently. (*San Francisco Times*, Oct. 22, 1868.)

The total list of casualties due directly to the earthquake numbered 5, and about 25 more occurred from secondary causes. The total loss of property was variously stated from $300,000 to $5,000,000. However, a careful estimate of damages made a day or two after the disaster, placed it at about $350,000. (*San Francisco Bulletin*, Oct. 23, 1868.)

THE DISTRIBUTION OF INTENSITY THRUOUT THE STATE.

Healdsburg. — A good shaking. Heaviest shock ever felt. (*Democratic Standard*, Oct. 24, 1868.) Lasted about 10 seconds. Vibrations north and south. Clocks stopt. (*Alta California*, Oct. 22, 1868.)

Guerneville. — The earthquake was of great severity. It frightened my horse and he started to run away; but a large tree which had been cut nearly thru by choppers, and which they felled a few moments after the shock, was not overthrown by the shock. (I. E. Thayer.)

Santa Rosa. — Severest shock yet felt. Lasted 10 seconds. Nearly all brick buildings in town more or less injured. Many chimneys down. (*Alta California*, Oct. 22, 1868.)

Violent and somewhat protracted earthquake. Vibrations at first from west to east, but suddenly changed from south to north, and continued about a minute. Damage to property considerable. Several brick buildings cracked. At Windsor it was lighter than in Santa Rosa, and farther north still lighter. At Sonoma, Sebastopol, Bodega, and elsewhere, the shock was severe but little damage was done. (*Santa Rosa Democrat*, Oct. 26, 1868.)

Petaluma. — Vibration north to south, 10 seconds in duration. Several brick buildings injured and many chimneys. (*Alta California*, Oct. 22, 1868.) Oscillations from east to west; 3 distinct shocks lasting in all 10 to 15 seconds. (*Petaluma Argus.*)

San Rafael. — Terrible shock. Vibrations southeast to northwest, for fully a minute. (*Alta California*, Oct. 22, 1868.)

Napa. — Violent shock in northeast direction for 30 seconds, accompanied by low rumbling sound. Some slight damage. (*Alta California*, Oct. 22, 1868.)

Most severe shock ever felt. Lasted 40 seconds. No serious damage to buildings. Five miles west of Napa a number of trees were overthrown. (*Napa Reporter.*)

Vallejo. — Earthquake severe. Many chimneys down. (*Alta California*, Oct. 22, 1868.) Heaviest shocks ever felt in Vallejo. One chimney and some plaster down. Dishes thrown from shelves. Bay smooth. (*Vallejo Recorder.*)

Mare Island. — Chimneys were thrown, and some buildings were considerably shaken. Shock accompanied by rumbling sound.

Chico. — A perceptible moving of the earth. Lamps and dishes rattled. (*Chico Courant*, Oct. 23, 1868.)

Colusa. — Slight shock. Not over a dozen people noticed it. (*Colusa Sun.*)

Marysville. — Shock very light; noticed by a few only. (*Alta California.*)

Sacramento. — Pretty heavy shock from southeast to northwest. Plaster cracked.

Lasted 20 to 30 seconds. Water in the river receded, shoaling vessels, and then rose with a rush. (*Sacramento Union.*)

Knight's Landing. — "I was running a flour-mill at Knight's Landing in 1868. While the shock was not unusually severe at that place, it did some damage. The gable end of the mill warehouse was thrown down, not by the vibration of the quake, but by a pile of wheat being thrown down against it and forcing the end of the building out. I was out in a pasture at the time, pumping water for stock, and noting the water sloshing from one end of the trough to the other, I wondered as to the cause, as I had not felt the shock on account of the motion of my body in working the pump. On looking up I noticed the trees swaying back and forth, with no wind, and I knew it must be an earthquake. There was some little loss in the town in the way of broken crockery, chimneys, etc. The heaviest shock was along the edge of the valley near the Coast Ranges. In this county it was heaviest at Winters, where it demolisht John Wolfskill's house, a stone building, and did considerable other damage." (E. H. Eastham.)

Woodland. — Two severe shocks, from southeast to northwest, lasting a minute. (*Alta California*, Oct. 22, 1868.)

Suisun. — Severe shock, north and south. Slight damage. A few brick buildings cracked. (*Solano Sentinel*, Oct. 22, 1868.)

Solano. — Severest shock ever felt. Sudden upheaval, attended and followed for nearly a minute by a swaying in a north and south direction. No damage except cracks in walls. (*Sacramento Daily Union*, Oct. 24, 1868.)

Martinez. — Some buildings damaged by cracks. Waters in front of town caused to dance. Fish rose to surface. (*Martinez Gazette.*) Court-house wrecked. (Holden.)

Walnut Springs. — Heaviest shock ever felt. Goods in store thrown from shelves. (*Alta California*, Oct. 22, 1868.)

Antioch. — Severe shock from southwest to northeast for 30 seconds. Several fissures formed in the ground. (*Sacramento Daily Union*, Oct. 23, 1868.)

Benecia. — At the repairing works of the Pacific Mail Steamship Company, an iron shaft of one of the side-wheel steamers was lying on the ground in a north-south direction. The earth moved from under it 9 inches, lengthwise, but in what direction is not recorded. (George Davidson.)

Stockton. — "I was then 13 years old. With a younger brother and a third boy I had, on the morning of October 21, 1868, gone to the edge of the tule marsh about 2 miles southwest of Stockton, to shoot ducks. The morning flight of birds was over, and we were returning home. My brother had his gun at the shoulder and was aiming at a meadow-lark when the earth movement commenced. The lark flew up without apparent cause, the gun moved up and down slightly, and I at once had a feeling that something unusual was happening. Within a few seconds the water-fowl, hidden from us by the tule but in countless numbers, rose with a noise like rolling thunder and took flight toward the west; while 0.5 mile to the east a small band of cattle, with heads down and tails in the air, were racing across the country. By this time the earthquake was probably at its maximum, and, looking east, I could distinctly see the ground's surface in wave-motion, the waves apparently moving across the line of vision. During the time this motion continued, it was not perceptible as a vibration to the sense of feeling. All three of us admitted, however, that the earth felt insecure under foot. We could detect no effect on the water surface of the swamp. Stockton escaped with only here and there a cracked brick wall." (C. E. Grunsky.)

Most severe shock ever felt. Vibration from northwest to southeast. West of Lodi and Woodbridge, shock was as severe as in Stockton. (*Stockton Independent.*)

In a slough water was thrown into ebullition to a height of 2 feet for a few minutes. (*Stockton Gazette.*)

Berkeley. — The State Institution for the Deaf, Dumb, and Blind lost 11 chimneys and 2 gables, and rear walls were cracked in several places. (*Oakland News*, Oct. 21, 1868.)

Oakland. — Shock preceded by a rumbling sound. Pans of milk and tubs of water emptied almost in a moment; trees whipt about like straws; many houses twisted 5 or 6 inches out of square, particularly those on brick foundations. The crashing of falling brick at the Deaf, Dumb, and Blind Institute was heard a few blocks to the south before the shock was felt. Chimneys very generally down, particularly those on south and east sides; in some parts all chimneys thrown. Many chimneys twisted, if not thrown. Many brick buildings were shattered, and several wharves went down with loads of brick, coal, hay, etc. In Brooklyn, as in Oakland, many chimneys were broken off at the roofs. (*Alta California*, Oct. 22, 1868.)

The drawbridge of the San Francisco and Oakland Railway was thrown out of place about 8 inches. (*Centennial Book of Alameda County*, p. 266.)

Thruout the city chimneys and walls fell south. (*Oakland News*.)

Of two houses next each other the older one stood on posts 4 feet above the ground, while the other was supposed to be earthquake proof. The basement walls were solid and of good workmanship. The old house was badly shaken, but not injured; the earthquake-proof house had the basement walls cracked, all the ceilings thrown down, and the marble mantel in each of the rooms thrown upon the floor. (Geo. Davidson.)

Alameda. — Shock very severe. Scarcely a house escaped uninjured. (*Alta California*, Oct. 23, 1868.)

San Leandro. — The earthquake was much more severe than in Oakland or Alameda. Not a building escaped some injury. Chimneys fell north and south. The court-house was in ruins. A tank 10 feet wide and 6 feet deep was entirely emptied of water. The bed of San Leandro Creek, which had been dry for several months, became filled with a stream of water 6 feet wide and a foot deep. A team of mules descending a hill 9 miles east of Haywards, were thrown to their knees. A rumble preceded the shock. The rangers on the old Peralta rancho said the crack past through the foot-hills on to Oakland. (Various old residents.)

San Lorenzo. — The limbs of a sycamore tree, 24 feet high, struck the ground. (G. Hyde.)

Flat irons and a kettle were jerked off the stove southward. (Mrs. Adams.)

House and barn were both prostrated. (Mrs. E. H. Gansberger.)

A house was thrown off its foundations. Chimneys were thrown northward. (E. Llewellyn.)

Haywards. — The crack past diagonally up the Haywards Hill and crost 3 feet from the south corner of the old hotel; past just east of the Odd Fellows' Building, through the Castro lot, tearing off a corner of the adobe house which stood where the jail now is, on through Walpert's Hill toward Decoto. By the hotel the crack first opened 18 to 20 inches, but soon closed to 5 or 6. It was of unknown depth; several balls of twine, tied together, with an iron sinker, failed to find bottom. There was no water in the fissure, for the iron came up dry. From the corner of B and First Streets another crack past nearly eastward toward the hills, and faded out by the sulfur spring about 1.5 miles distant. (Mrs. Wm. Haywards.) In a general way, the crack from Haywards to beyond Decoto past from 100 to 300 feet above the base of the hills. Practically not a house was left on its foundations in Haywards. At one place south of town the fault showed a throw of some 3 feet. (W. H. Weilbye.)

"Since October 5, 1862, I have lived in Haywards, Alameda County, and I well remember the earthquake of October, 1868. Being lame and having used a cane from childhood, I had never walked without it until that morning. I was working in my shop at the time. On feeling the terrible shock, and on the impulse of the moment, I managed to get out of the building and into the street, some 18 feet distant, but on recovering from my fright I found I had left my cane in the shop. I managed to get back into the building, got my cane, and started for my house only a few yards away. The house had been thrown from its foundations, the chimney had been torn from the roof, and the porch had been wrencht away. Dishes were broken and everything was in confusion. I discovered that most of the houses were in the same condition as my own — thrown from their foundations, with chimneys down, porches knocked sideways, etc. All the while the ground was shaking and continued to shake for days and even weeks; but each shock was lighter than the last. On a certain piece of ground near the Haywards Hotel there was a common board fence, the boards abutting on the post. After the quake the boards lapt one over the other about 5 inches, the ground seeming to have been prest together that much. On going down the county road toward Oakland, we came to Mr. A. L. Rockwood's house, which had been thrown from its foundation and one end thrown into the cellar. The house was badly wrecked. In the south part of the town there was a flour mill on a foundation about 4 feet high. This building was thrown to the ground and wrecked. On the ground which is now the plaza stood a new brick warehouse filled with grain from the season's crop. The building was completely torn to pieces; grain was spilt from the sacks, and everything was in a mess. The building was 300 feet long by about 60 feet wide. A wooden warehouse about the same size shared the same fate as the brick. On B Street the ground opened about 2 inches, and water and sand were forced from the opening. Some springs were closed, while others were opened or made to flow more freely. Many wells were affected in the same manner. Mr. Charles Herman, who was in the baking business, was driving back to Haywards after delivering bread. Looking up the road, he saw the ground coming toward him in waves, and when the motion struck his horse, she went down on her knees. Mr. Herman thought the world had come to an end. As he neared the San Lorenzo Creek, he noticed that the water had been thrown out of the bed of the creek on to the road.

"At San Leandro the earthquake destroyed the brick court-house, which was then located there. A Mr. Joslyn was killed in attempting to escape from the building. Many buildings were much damaged in that town as well as in Haywards. The earthquake was the direct cause of the death of 2 persons in Haywards." (George A. Goodell.)

The crack past thru a gravel quarry practically on the summit of the first range of hills. (O. Hill.)

The crack below Haywards Hotel was 12 inches wide. It ejected water and white sand. A fence which traversed a hill from north to south was crost by the crack, and had the ends of the boards loosened from the posts. Gradually these boards lapt over one another, until within a couple of weeks they overlapt several inches, the progress of the overlapping being noted from time to time by a pencil mark. The "cap" board of the fence was also archt up in consequence of this movement. Large waves were set up in the soil. The house was moved southward, while a neighbor's was tipt northward. (D. S. Malley.)

The rumbling preceding the shock came very distinctly from the bay, and the plain in that direction rolled like huge waves of the sea coming toward Haywards. (F. Allen.)

The crack opened parallel to Castro Street, 35 to 50 feet below Haywards Hotel. The fence passing diagonally up the hill was shortened 6 inches. (P. McKeever.)

A stove in the house was thrown north. (J. Wolput.)

A crack 3 to 4 inches wide started from the Powell place and struck across toward the county bridge next to Nettleton's, passing west of it; crost the creek, demolisht a fence completely, and past on toward the Strowbridge residence, where the house was badly shattered. (Mrs. Hamer.)

The shock was from southwest to northeast. The ground opened from 6 inches to 2 feet, and water with sand was ejected to a height of from 1 to 3 feet. North of the village a ridge of ground 3 feet wide was raised 2 feet. By the time the shock was over, nearly the whole place was in ruins. Near Hayward's Hotel the hill shifted a good deal, and a crack opened for several hundred feet. On the hills there were several new springs. In the first 12 hours after the main shock there were 36 after-shocks. Between Haywards and Mission San Jose there were numerous cracks, so that it was difficult to drive a stage between the two towns. (*Alta California*, Oct. 22-25, 1868.)

Mt. Eden. — All the shelving on south side of the 2 stores of the town was thrown down. (*Alta California*, Oct. 22, 1868.)

Alvarado. — Shocks were violent. The ground opened in several places and water issued. (*Alta California*, Oct. 22. 1868.)

Centerville. — A dwelling-house was partly destroyed and 2 stores were wrecked. Hotel settled 2 feet. (*Alta California*, Oct. 22, 1868.)

Roberts' Landing.—"Our house broke in three pieces, each part falling outward. A boiler of hot water was on the stove, and with the first deafening jolt, the hot water came my way, giving me a bath I have never forgotten. Horses fell to the ground and men clung to some quince trees near.

"Captain Petersen, of the steamer San Lorenzo, who is now deceased, was walking along the road to Roberts' Landing when he heard a great rumble off across the fields toward San Leandro. He lookt quickly in that direction, and over a mile away could see the great wave rapidly approaching. He rushed to the side of the road and had caught hold of the fence by the time the shock broke. Near him on the road a 6-mule team was drawing a load of grain, and all the mules fell flat and could not regain their feet until the great jolt was over. During the 3 or 4 succeeding days there were 150 shocks; none, of course, with anywhere near the extent of the heavy one." (R. C. Vose.)

Decoto. — Opposite Decoto a crack appeared about one-third of the way up the slope. It opened 10 or 12 inches at the surface and faulted about as much on the plains side. The level lands waved like the ocean, and the waves seemed to approach from the south. (Mr. Decoto.)

Tyson Lagoon, south of Niles. — A tank swayed north, then south, and fell. The lagoon parted lengthwise down the middle and threw water and mud both ways. After the earthquake the lagoon was dry for 3 years. It has no outlet. Rumblings preceded the main shock and many of the after-shocks. (Mrs. Wm. Tyson.)

A crack went thru the old Shinn place, crost the Centerville-Niles road about 0.6 mile southwest of the Southern Pacific Railway track, and past thru the Tyson Lagoon. (H. Tyson.)

Niles. — The water from the tank slopt nearly east. Rumblings preceded the after-shocks. These were more severe than in April, 1906. (C. Overacher.)

A crack past thru the Shinn and Tyson places. (C. Bonner.)

Irvington. — Thru the north side of town a crack split the hillside, opening 7 or 8 inches and showing a fault of 8 or 10 inches. It crost the country road 500 feet north of the Southern Pacific Railway depot. Its trend was N. 45° to 50° W. From these low hills the crack seemed to pass over into the tule ponds north of town. The Tyson Lagoon dried up after the quake. The rumbling preceding the shock came from the north. (R. B. Crowell.)

The railroad tracks north of the station were badly twisted for several hundred yards. (M. Torry.)

In one place the crack on the hillside divided, and formed a narrow island, 8 or 10 feet across, which dropt below the general level of the sod 8 or 10 inches. Springs were opened up on Mission Peak. (H. Crowell.) The crack which past thru the town continued southward down the hillside about 0.5 mile northeast of the railway track. It opened 5 to 8 inches, not faulting.

"I was then about 15 years of age. My home was near Irvington. When the shock came, I was alone in the house with my baby brother. My mother was in the milk house, about 10 steps from the kitchen door. She called to me to get the baby. Tho I was thrown the length of the dining-room, I managed to get the child over my arm, face down, and a pillow on top. Then, falling and crawling, I worked my way back to the open kitchen door. My mother was on the ground. Every time she tried to get up, she was thrown again, and the milk in the buckets was spilt over her. My two brothers, my step-father, and the hired man were also down and were trying to get to the house by crawling and falling. As I sat there, I could see the ground in waves like the ocean. After the main shock, I think we had 100 shocks during the first 24 hours. The ground opened; we traced a crack thru town, and the ground settled several inches in one place. Not a house was left with a chimney on it. Our safe broke thru the floor, and the piano was out in the room nearly to the opposite side." (J. McD. Preston.)

Mission San Jose. — "I was curled up in a big rocking-chair, reading, and my two sisters were outside playing, when suddenly there came a swaying of the house. This lasted only a short time; then the house began to shake in earnest. My sisters began to cry and scream. I jumped out of the chair to go to them, and ran from the room, bumping against both sides of two doors. I finally reached the porch and succeeded in catching hold of a post. I distinctly remember that the pump in the yard was pumping as if some one had hold of it; and small rocks on the hill in front of the house were rolling down into the creek. The milk pans had been resting on shelves of slats; some pans slipt entirely out, some only halfway. The milk and cream were on the floor. My brother was hauling a load of wheat to San Jose. When the earthquake was at its worst, he thought his team was choking down and jumped off his wagon to find he could hardly stand. I was told at the time that the water spurted up in the streets of San Jose, and out in the road between Milpitas and San Jose, to the height of several feet. The old Mission church, which was of adobe, was shaken down, as were several other buildings at the same place. On the mountain above the old Mission, just above a place called Peacock Springs, a great crack in the earth appeared, which lookt as if the lower part of the mountain had parted and slipt down. Many times I have crost the bridge which was built over the crack, and stopt and thrown rocks down to see if I could tell how deep it was." (Mrs. N. Ainsworth.)

Along the hills back of the town and southward, passing thru the present Sinclair and Stanford ranches, the crack opened. Generally it was 10 or 12 inches wide, and faulted some 18 inches on the valley side. (A. Kell.)

The shock was preceded by a rumble passing to the northwest. Adobe building not seriously injured. Crack at Irvington and on the side of Mission Peak confirmed. (J. Sunderer.)

Brick store was cracked. Confirms cracks at Irvington. (S. Ehrman.)

Chimneys fell north and south, as they did also on April 18, 1906. (S. Murphy.)

Warm Springs. — The crack past along the foot-hills at an elevation of 350 to 450 feet from Niles southward, back of Mission San Jose, disappearing near the county line. In some places the fissure showed a fault of 10 to 12 inches. (H. Curtner.)

The warehouse and wharf on the slough fell, also Dixon's house. Cracks in the vicinity of Milpitas flowed artesian water for 48 hours after the shock. (Mr. Durkee.)

Milpitas. — Along Coyote Creek the ground was cracked from Boot's ranch to the San Francisco Bay, the cracks being on the bay side and following the winding of the creek. As in 1906 much water was ejected from the cracks, and Coyote Creek rose. (W. Bellou.)

Calaveras Valley. — Only one or two chimneys were dislocated. (J. Patton.)

Santa Clara County. — Messrs. J. W. Hines and C. Valpey, and Miss Bennett, of San Jose; Mr. H. B. Valpey, of Santa Clara; Messrs. P. Anderson and C. B. Mendor and Mrs. W. Smith, of Berryessa, all of whom were intimately acquainted with this section of the country in 1868, report that there was no crack south of the county line.

Alcatraz Island. — A rumbling sound accompanied the shock, and the island vibrated with a jerking motion. (Dr. L. Hubbard, U. S. A., in *San Francisco Times*, Oct. 22, 1868.)

Colma. — "I was then 16 years of age and lived in San Mateo County, a mile or so south of the present town of Colma. With my father I was digging and sacking potatoes in a field. I was sewing up a sack, when my father said: 'Look at that mountain. What is the matter with it?' We felt no earthquake, but the mountain seemed to be bobbing up and down. A freight train was going north along the S. P. track. Shortly after we had observed the mountain apparently moving, the earthquake reached the railroad track and the freight train appeared to gyrate like a snake. The next instant we felt it. The shock was very severe, throwing us to the ground and knocking over sacks of potatoes. A band of loose horses, including a lot of young stock, in an adjoining field, ran around the field at great speed, utterly panic-stricken. The house we lived in was in a flat some 0.5 mile from where we were at work. When we reached it, we found that milk pans in the pantry had been entirely emptied of their contents. Some panes of glass were broken and some crockery and glassware were thrown down and destroyed; but the house, a light frame building, was not injured. There were 48 shocks between the first one and midnight that night.

"I do not now recall any serious damage done in San Mateo County. There were some landslides occasioned along precipitous hills and creek banks, but the buildings in that section were all frame, and none of them were destroyed to my knowledge." (J. A. Graves.)

San Mateo. — Vibrations from the north for 15 seconds. (*Alta California.*)

Redwood City. — The court-house was wrecked and other buildings were damaged. The shock seemed to come from the southeast and lasted 30 seconds. (*Redwood Gazette*, Oct. 24, 1868.)

Mountain View. — Severest earthquake yet felt. Far worse than that of 1865. Shock from northwest to southeast. (*Alta California*, Oct. 23, 1868.)

Santa Clara. — Severe shock. Motion northeast to southwest. No serious damage. (*Alta California*, Oct. 22, 1868.)

San Jose. — "The most terrible earth shock ever experienced in this section since the settlement of this country by Americans, occurred yesterday morning at 8 o'clock. A dense fog hung over the city at the time, when, with scarcely a premonitory tremor, the shock was upon us in all its force. Buildings and trees seemed to pitch about like ships in a storm at sea. Fire walls and chimneys were thrown down in all parts of the city. The heavy brick cornice of Murphy's building at the corner of Market and Eldorado Streets fell to the ground. The Presbyterian Church has sustained an immense damage. The brick turrets are all down, and large portions of the steeple were precipitated thru the roof to the floor, crushing the organ and causing great damage to the gallery and fixtures below. The walls of the steeple are almost a total wreck and will have to be taken down. $5,000 would not make good the damage done to the church. The large water-tank on the roof of Moody's flour mill fell thru the roof, carrying destruction in its course. Their wooden store-house, 100 feet in length, filled with grain, is a total wreck and the grain badly mixed. Two huge chimneys of the San Jose Institute were thrown down, one of them crushing thru into the rooms below. A portion of the rear wall of Welch's livery stable fell. Otter's unfinished block at the corner of First and St. John Streets, sustained a very serious damage. There is not a brick building in the city that is not more or less injured. Brick walls are everywhere wrenched and cracked and many of them are ready to fall. Another such shock would precipitate many of our brick buildings to the ground. The brick cornice of the Masonic Hall Building will have to be taken down, and the entire building, in its present condition, is decidedly unsafe for occupancy. A large quantity of crockery and glassware was broken. The destruction of plate-glass windows is very great, and much havoc is done to plastering generally. The new court-house stood the shock admirably. Some little crumbling of plaster decoration is all the damage it sustained. The lesson of the earth shock is: Erect no more high church steeples, and build no more brick buildings above 2 stories in height, and those only in the most substantial manner. A second but much lighter shock was experienced at about $10^h 30^m$ of the same day, and shortly thereafter a third shock of like character." (*San Jose Mercury*, Oct. 22, 1868.)

Where the Milpitas road crosses Coyote River, the banks were shaken together and the river-bed filled up. (*San Jose Argus*, Oct. 24, 1868.)

Old Gilroy. — The building shook and rocked till the occupants became seasick. The oscillation seemed to be southwest and northeast, and lasted about 30 seconds. No damage was done beyond some broken bottles in the drug store. (*Gilroy Advocate*, Oct. 24, 1868.)

Rumble preceding the shock came from the north. Chimneys fell north and south. It was fully as heavy as the shock of 1906, but not so long. The old adobe buildings were much damaged. (W. D. Dexter.)

The shock was not so severe as in 1906. (Messrs. Rice, C. Wantz, Bryant, Gilman.)

Pacheco. — Every brick house in town was ruined. (*Alta California*, Oct. 22, 1868.)

San Juan. — The shock was the heaviest since 1865. Lasted 30 seconds. (*Alta California*, Oct. 22, 1868.) No chimneys fell; 2 brick walls were cracked. (C. Bigley.)

Santa Cruz. — Severe shock from east to west, preceded by rumbling noise. Lasted 15 seconds. Several brick buildings badly cracked. (*Alta California*, Oct. 22, 1868.) Second only to the earthquake of 1865. Vibration from northeast to southwest for 30 to 40 seconds.

At Watsonville chimneys and plastering suffered but little. At Eagle Glen a slide 50 feet wide carried rocks and trees 1,000 feet. In Soquel a few chimneys were dislocated.

Half Moon Bay to Pescadero. — Chimneys down or twisted, along the coast. (T. G. Phelps, Holden's report.)

Near Pescadero limbs fell from the redwoods and large pieces of rock rolled down the mountains. (*Grass Valley Union*, Oct. 29, 1868.)

Monterey. — A smart little earthquake, traveling from north to south. No particular damage. (*Monterey Gazette.*)

Downieville. — A slight earthquake was felt. (*Mountain Messenger*, Oct. 24, 1868.)

Grass Valley. — Lamps vibrated. Vibrations from southwest to northeast. (*Alta California*, Oct. 22-24, 1868.)

Nevada City. — Three distinct shocks felt. Also felt at You Bet. (*Nevada Transcript.*)

Placerville. — Shock plainly felt. (*Mountain Democrat*, Oct. 24, 1868.)

Amador County. — The earthquake was distinctly felt at Pine Grove and Volcano. (*Alta California*, Oct. 25, 1868.)

Jackson. — Earthquake perceptible to a number of people. (*Amador Dispatch*, Oct. 24, 1868.)

Folsom. — A slight shock. Clocks stopt. (*Folsom Telegraph*, Oct. 24, 1868.)

Sonora. — A slight shock. (*Alta California*, Oct. 22, 1868.)

Tuolumne. — Shock lasted 10 to 15 seconds. Severe. (*Tuolumne City News*, Oct. 23, 1868.)

Snelling. — Hard shock. No damage. (*Merced Herald*, Oct. 24, 1868.)

Visalia. — Shock felt by few persons. (*The Delta*, Oct. 28, 1868.)

Nevada. — At Gold Hill and Carson, shock perceptible to people awake, and a few people awakened. (*Territorial Enterprise*, Oct. 22, 1868.)

The shock was apparently not felt in Ukiah, Yreka, San Luis Obispo, Los Angeles, Reno, Virginia City, Alpine County, Yuba County, Trinity County, or Oregon.

SUMMARY.

A review of the facts above presented regarding the earthquake of 1868 makes the following summary statement possible:

1. The earthquake of 1868, like that of 1906, was due to an earth-movement on a rupture plane or shear zone which was manifest at the surface as a fault-trace.
2. The fault on which the movement took place was quite distinct from the San Andreas fault.
3. It parallels the latter at a distance of about 18.5 miles to the northeast.
4. Like the San Andreas fault, it is coincident with an old diastrophic line upon which similar movements have been recurrent in time past.
5. The old diastrophic line is marked by a degraded fault-scarp, which bounds the valley of San Francisco Bay and Santa Clara Valley on the northeast.
6. Along this line there are certain geomorphic features analogous to those which characterize the San Andreas Rift.
7. The fault-trace of the fault of 1868 was much shorter than that of 1906, having a known length of only 20 miles.
8. The amount of horizontal movement, if any, was much less than on the San Andreas fault in 1906, and its direction is unknown.
9. The vertical movement appears from the accounts given to have been small also, and to have been manifest as a downthrow on the southwest or bay side, altho this is not satisfactorily established.
10. The fault-trace was characterized for the most part by a crack which in places, particularly on the lower ground, was superficially gaping. Associated with this main crack there were auxiliary branching cracks; and on the alluvial bottom-lands about San Francisco Bay there were numerous secondary cracks which were usually not discriminated by the observers of that day from the fault-trace.
11. In harmony with the shortness of the fault-trace and the small movement apparent along it, the area of destructive effect was much smaller than in the case of the earthquake of 1906. This was true also of the entire area embraced by the isoseismal II R. F. While the data are insufficient for plotting the isoseismals satisfactorily, it is nevertheless clear that these curves plotted as ellipses on the map of California would have had much shorter major axes than in the case of the isoseismals for the earthquake of 1906; while the minor axes in a northeast-southwest direction would not differ greatly for the two earthquakes. We have no authentic reports of the earthquake north of Chico nor south of Monterey, altho perceptible tremors probably did extend further south. On the other hand, in a direction normal to the fault-trace the earth-wave made itself felt as far as the State of Nevada.
12. The intensity was X in the vicinity of the fault-trace at Haywards.
13. In San Francisco the chief damage caused by the earthquake was, as in 1906, on the made land and along the margin of the old shore and marsh border. But little damage was sustained by structures on the rocky slopes.
14. The foot of Market Street, San Francisco, is about midway between the San Andreas Rift and the fault-scarp upon which movement occurred in 1868. The city

has, therefore, to reckon with the latter as well as the former in its future career, and consequently should be doubly prudent in the location and structure of its important buildings.

15. The cities on the east side of San Francisco Bay are less concerned with the San Andreas Rift, but are more immediately affected by the proximity of the diastrophic line marked by the front of the range of the Berkeley Hills.

16. The interval between the disastrous movement of 1857 on the San Andreas Rift and the movement on the Haywards fault in 1868 was 11 years.

THE EARTHQUAKE OF 1865.

About $12^h\ 45^m$ P. M., on October 8, 1865, a moderately severe earthquake shook middle California. Most of our information regarding it is assembled in Holden's Catalogue of Earthquakes. In the *Sacramento Daily Union* of that date it is described as the most violent ever experienced there. After several vibrations a second or two intervened, and the shaking was then repeated more violently than at first. The vibrations seemed to be east and west, but a few people thought they were from southwest to northeast. Clocks stopt, and there was a general feeling of dizziness and nausea. The same paper states that at Stockton the shock was heavy and seemed to pass from north to south, but that no damage was done. At Petaluma there were two severe shocks in quick succession, vibrating from northwest to southeast. The shock was the heaviest experienced up to that time. All brick buildings were more or less injured. The first shock was from the northwest to the southeast, followed by a general shaking or rolling, closing with a jerk. At San Jose the shock was very severe. Brick walls fell and the convent bell tolled. At New Almaden a large brick store-house on the hill was nearly demolisht. Several houses in the village were thrown down. The earth opened and closed again. Chimneys in different parts of the county were thrown down. (*San Francisco Bulletin*, Oct. 12, 1865.)

At Watsonville there was a heavy shock. The earth opened in several places (secondary cracks), throwing up water. At Santa Cruz the shock was apparently heavier than elsewhere. Every brick building was reported ruined. The motion was apparently east and west. The lowlands along the river opened and spouted water like geysers. Some wells went dry or were filled with sand. The tide rose very high at the time of the shock and fell very low immediately afterwards. (*Bulletin*, Oct. 9, 1865.)

"Monterey escaped unharmed." (*Sacramento Daily Union*, Oct. 9, 1865.)

After shocks were reported at San Jose, Santa Clara, and Santa Cruz.

There is no record of the shock having been felt at Marysville, Yreka, Eureka, or in Alpine County; the *Mountain Messenger* of October 14, 1865, states that it was not felt at Visalia nor in Los Angeles. The *Bulletin* of October 17, 1865, states that it was not felt in Santa Barbara.

In San Francisco, according to the *Bulletin* of the date of the earthquake, there was a violent shock lasting about 5 seconds, followed almost instantly by another much heavier shock, which continued for 10 seconds or more. Vibrations appeared to be nearly east and west, but some experienced observers said that the movement was in the same direction as previous shocks — nearly northeast and southwest. The commencement of the shock was accompanied by a rumbling sound. During the following evening there were two or three slight after-shocks. The effects of the earthquake were visible in every street. No buildings were entirely demolisht, but the damage aggregated many thousands of dollars. The most important damage to buildings occurred at the following localities:

Corner Mission and Third Streets. Upper half of front of 4-story brick building fell; poorly constructed.
Northeast corner Battery and Washington Streets. Old Merchants' Exchange ruined.
Beale Street, near Market.
Kearney Street, near Sutter.
Jackson Street and Stout Alley.
Mission and Fremont Streets.
Battery and Union Streets.
Corner Kearney and Washington Streets. City Hall had front wall badly cracked and entire building rendered unsafe.
Washington Street, near Sansome.
Market Street, near Sansome.
Pine Street and Front Street.
Market and Pine Streets.
Sacramento and Battery Streets.
Sacramento and Webb Streets.

On the marshy lands in the vicinity of Howard and Seventh Streets the ground was heaved in some places and sank in others. Lamp-posts were thrown out of perpendicular, gas-pipes were broken, etc.

It appears probable from these scant records that the seat of the earthquake of 1865 was somewhere in the Santa Cruz Mountains, between San Jose and Santa Cruz. If this conclusion be accepted, it seems further probable, in the light of recent events, that it was due to a minor movement along the San Andreas Rift. It was probably a somewhat less severe earthquake than that of 1868. The earth movement which gave rise to the shock extended neither so far south as in 1857 nor so far north as in 1906, but appears to have pertained to that portion of the Rift affected in 1906 rather than to that affected in 1857.

The only other earthquake which can definitely be referred to a movement along the San Andreas Rift was that of April 24, 1890, which, according to Messrs. F. Abby and Charles Bigley, of San Juan, opened a fissure at that place on the line of the Rift. The railway bridge at Chittenden was displaced, as it was in 1906.

THE EARTHQUAKE OF 1857.

Information regarding the earthquake of 1857 is scant and generally unsatisfactory as to details. California at that date was very sparsely populated, particularly in the southern Coast Ranges, where the seat of the disturbance was. The only records that have come down to us are those of Trask, in the Proceedings of the California Academy of Sciences, Vol. I, 1873; a note by J. S. Hittel in his "Resources of California," 1863, p. 42, and some notes in Holden's Catalogue of Earthquakes. These brief notes are supplemented by the statements of a few old residents who recall the event, some of whom were in the zone of acute disturbance at the time. The data, while insufficient for a satisfactory account of the earthquake, warrant the statement that it was due to a displacement or fault in the San Andreas Rift, along its extent from Cholame Valley to the San Bernardino Valley, a distance of about 225 miles.

According to Dr. Fairbanks, who has recently been over the course of the Rift in the southern Coast Ranges, the residents along that line have either very vivid recollection or very strong tradition regarding the rupturing of the ground at the time of the earthquake; and Dr. Fairbanks' field observations confirm the probable truth of their statements. It appears to have been generally recognized by people familiar with the southern Coast Ranges that the shock was due to or associated with the rupture of the ground, and the line of rupture is commonly referred to by the country people as the "earthquake crack." This crack, as opened in 1857, with differential displacement of unknown extent and direction, is still pointed out as a remarkable phenomenon from Cholame Valley southeastward along the northeast side of the Carissa Plain, through the Tejon Pass, thence along the southwest side of the Mojave Desert, past Lake Elizabeth and Palmdale, to the Cajon Pass and thence to the south side of the San Bernardino Range. The shock was felt from Fort Yuma to Sacramento, and the total area sensibly affected was probably not much less than in the earthquake of 1906. It was severe both at Los Angeles and San Francisco. At Los Angeles shocks continued at intervals during the day. Mr. H. D. Barrows, who was in that city on the day of the earthquake, in a letter dated August 5, 1906, communicates the following information as to his experiences:

> The great earthquake of January 9, 1857, in southern California, opened the ground for nearly 40 miles in a straight line near Elizabeth Lake. I had a brief account of it in the *San Francisco Bulletin* about February 1, 1857 — my letter (signed "Observador") being dated January 28, 1857.
>
> Only one life was lost by that great convulsion of nature, a woman being killed at Fort Tejon by the falling of adobe walls; and, considering the colossal disturbance, very little damage was done to buildings here in Los Angeles. This is probably accounted for by the fact that our buildings were of only one story, with walls 2.5 and 3 feet thick. At the time of the great upheaval, I was in the yard at the south side of the adobe house of William Wolfskill, the pioneer, near the present site of the Arcade Depot in Los Angeles. I first stumbled toward the west, and was almost thrown down; then, after a brief period, I commenced to stumble in the opposite direction. Other persons near me stumbled in similar fashion. The long wide corridor on the south side of the Wolfskill house was hung with grapes, and I noticed that they swung back and forth clear up to the rafters. Water in tanks was thrown out in numerous instances, clocks were stopt, etc. The movement seemed to be comparatively slow, giving things time to recover after moving in one direction. If the motion had been short and sudden, the damage would have been appalling.[1]

All the houses in Santa Barbara were damaged by the shock of 11^h 20^m P. M., January 8. (Perry, Holden's Catalogue.)

At Visalia it was difficult to stand erect; treetops waved several feet to and fro; it was equally severe at places within 50 miles north and south. There were several shocks felt at Stockton and Benson's Ferry, and the principal one was very severe at Sacramento, Los Angeles, and Monterey. (*San Francisco Bulletin*, Jan. 9, 1857.)

At San Francisco the main shock was preceded by 4 slight shocks at 11^h 20^m P. M., January 8; 11^h 33^m, 4^h 15^m, and 7^h A. M., January 9. The main shock stopt a jeweler's clock at 8^h 13^m 30^s A. M. Prof. George Davidson, who was in the city at the time, says the shock was sudden and sharp, preceded by no noise. He was lying north and south, and felt the movement in that direction. A friend who was lying east and west was thrown out of bed.

Professor Davidson also contributes the following:

> The wholesale grocery store of Goodwin Brothers faced east on Battery or Front Street, with its length of about 100 feet on Commercial Street. It was a 1-story brick structure about 15 feet high, with a flat metallic roof and a fire-wall of 3 or 4 feet above and around the roof. There were no windows nor doors on Commercial Street. The fire wall along Commercial Street was thrown bodily from the main structure into the street. The inner edge of the bricks was a straight line, at a measured distance of 6 feet from the base of the wall, while the general mass was scattered across Commercial Street. In the hardware establishment of Philip T. Southworth, along the west side of the east wall, there was a line of nail kegs, every one exactly 12 inches from the baseboard. Before the shock they had been placed close to the baseboard. These two conditions would indicate a movement of the earth from the northward and westward — roughly, from the north-northwestward. I do not remember damages to other buildings, but am satisfied there were no serious results to property. Among minor details were the effects of the shock upon one of the piled wharves, where a lot of bar-buoys had been left. They had been rolled about in every direction.

The following note on some of the effects of the shock in various parts of the state is extracted from Hittel's "Resources of California," 1863, p. 42:

> The waters of the Mokulumne River were thrown upon the bank, almost leaving the bed bare in one place. The current of the Kern River was turned up stream, and the waters ran 4 feet deep over the bank. The water of Lake Tulare was thrown upon its shores, and the Los Angeles River was flung out of its bed. In Santa Clara Valley artesian wells were much

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[1] Los Angeles is about 40 miles from the line of the Rift. A. C. L.

affected; some ceased to run, and others had an increased supply of water. Near San Fernando a large stream of water was found running from the mountains, where there had been none before. In San Diego and at San Fernando several houses were thrown down, and at San Buenaventura the roof of the Mission Church fell in. Several new springs were formed near Santa Barbara. In the San Gabriel Valley the earth opened in a gap several miles long, and in one place the river deserted its ancient bed and followed this new opening. In the valley of the Santa Clara River there were large cracks in the earth. A large fissure was made in the western part of the town of San Bernardino. At Fort Tejon the shock threw down nearly all buildings, snapt off large trees close to the ground, and overthrew others, tearing them up by the roots. It also tore the earth apart in a fissure 20 feet wide and 40 miles long, the sides of which vent then came together with so much violence that the earth was forced up in a ridge 10 feet wide and several feet high. At Reed's ranch, not far from Fort Tejon, a house was thrown down and a woman in it was killed.

The most interesting fact connected with the earthquake of 1857 is that it was due to an earth movement on the same diastrophic line as that on which faulting occurred on April 18, 1906. The movement in 1857 was, practically speaking, along the southern half of the known extent of the San Andreas Rift, while that of 1906 was along the northern half.

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